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[656]

Competition by roads, waterways and airways.

VI. (1)

Further information is given hereafter in connection with the steps taken by the Railways with a view to fighting the competition they are subjected to by other methods of transport. This chapter contains the main clauses of the British Road-Rail Traffic Act, 1933.

GREAT BRITAIN.

The Road and Traffic Act, 1933.

FOREWORD.

Even before the Great War, the British Railway Companies were interested in road transport, some of them having been authorised to engage in this work. With few exceptions, however, such transport was only for short distances and limited to traffic to or from the railway. In 1921, by the law which amalgamated the railways into four companies, they were authorised to organise such transport in a general way. This did not apply, however, to transport *by road only*.

The power to carry out transport by road alone was given the railway companies by the law passed by Parliament in 1928. This law applied to both passenger and goods transport.

As a general rule, the Companies have endeavoured to make use of the power thus given them, by means of agreements with existing road transport undertakings. In the case of passenger services, they bought shares in Road Transport firms and were represented on their Boards. Their object was to include road services in their organisation so that either rail or road transport could be used according to the circumstances, in the best interests of the public and after taking into account the economics and value of each method of transport.

In the case of goods transport, the Companies already operated services for collecting and delivering goods from door to door. They were now concerned in developing these and organising combined rail and road transport. They also made agreements with certain Haulage Firms who had the rolling stock and organisation necessary for carrying out road transport properly.

Two important laws affecting road transport have been passed recently : the 1930 Road Traffic Act, and the Road and Rail Traffic Act of 1933.

(1) See *Bulletin of the Railway Congress*, June to October, 1934.

The first, as its title indicates, only concerns road traffic and only affects the railways in so far as they themselves operate road services. It also affects them indirectly as proper regulation of the traffic will make competition less unfair. In the *Bulletin* for March, 1931, we published an article by Mr. Frederick G. Bristow, summing up the essential clauses of this act.

The second law : ***Road and Rail Traffic Act, 1933,*** affects the railways more directly. On the one hand, it requires road vehicles carrying goods to be licensed, and on the other, it gives the railways more liberty in the matter of rates.

Below we give the main clauses of this act.

First part.

The first part deals with road traffic.

Whereas the law of 1930 only required licences to be taken out in the case of vehicles used for public passenger services, i. e. omnibuses and automobiles, the law of the 17th November, 1933, requires every motor vehicle transporting goods by road to be licensed, whether on hire, used for commerce, or for carrying on the business of its owner.

This general rule has some exceptions. No licence has to be obtained in the case of :

1. vehicles used solely for agricultural purposes;

2. trailers which are not used for goods transport for hire or reward;

3. tramcars, trolley-buses, taxis used as such, and public service vehicles;

4. vehicles belonging to public maintenance services, the police, fire stations, ambulances, and break-down services;

5. vehicles employed in mine rescue work;

6. vehicles used for purposes specified in the regulations issued by the Minister of Transport.

An interpretive clause specifies under what conditions the transport of goods is not considered as being a transport against payment.

There are three classes of licences : A, B and C.

— « A. » class licences (public carriers' licences) are granted to professional transport firms who work for hire. They do not allow the holder to use the vehicle for transport in conjunction with his other business affairs, except for storing or warehousing goods in connection with his transport business.

— « B » class licences (limited carriers' licences) allow the holder to use the vehicle for goods transport in connection with his business or the running of his undertaking, and, in addition, according to the conditions laid down by the authority granting the licence, to carry out transport for payment.

— « C » class licences (private carriers' licences) cover transport carried out by the holder for his business or undertaking.

The licences are valid:

for two years in the case of the « A » licence ;

for one year in the case of the « B » licence ;

three years in the case of the « C » licence.

Licences for shorter periods can be granted in each of the three classes, either for working a seasonal undertaking, or for carrying out special work, or for some other object of limited duration.

The Authorities who investigate applications for licences are the Traffic Com-

missioners. Great Britain is divided into 10 traffic zones (provision was made for 13 in the 1930 Road Traffic Act). In each zone there are three Commissioners one of whom, the President, has a full-time appointment.

The law specifies the information to be supplied when applying for a licence.

*Every person who applies for a licence will be required to submit to the Traffic Commissioner a statement containing detailed particulars of the vehicles proposed to be used, and also in the case of an application for an « A » or « B » licence, the facilities for the transport of goods intended to be provided by him under the licence for other persons, including particulars of the district within which, or the places between which, it is intended that the authorised vehicles will normally be used for the purpose of carrying goods for hire or reward.

In addition, an applicant for an « A » or « B » licence must, if required, furnish (1) particulars with respect to his business as a carrier of goods for hire and of the rates charged; (2) particulars of any agreement or arrangement, affecting in any material respect the provision of facilities for the transport of goods for hire or reward, entered into by him with any other person by whom such facilities are provided; and (3) particulars of any financial interest which any other person providing haulage facilities has in his business.

Two important clauses, 6 and 7, deal with the difficult question of granting or refusing licences.

The Traffic Commissioners have full power in their discretion either to grant or refuse an application for an « A » or « B » licence, or to grant an application in respect of motor vehicles other than those of which particulars were contained in the application, or in respect of a less number of vehicles than those for the use of which authorisation was sought. On application for a « C » licence, the Commissioners must grant it, unless the applicant is the holder of a suspended licence, or unless the licence previously held by him has been revoked, in either of which cases the authorities have full power either to grant or refuse the application.

In exercising their discretion, the Traffic Commissioners must have regard primarily to the interests of the public generally, including those of persons requiring, as well as those providing, facilities for transport, and, in particular, must have regard in the case of an application for an « A » or « B » licence :

a) Where the applicant is the holder of an existing licence of the same class, to the extent to which he is authorised to use goods vehicles thereunder for the carriage of goods for hire or reward;

b) to the previous conduct of the applicant in the capacity of a carrier of goods;

c) to the number and type of vehicles proposed to be used under the licence;

d) in determining the number of vehicles to be authorised, to the need for providing for occasions when the vehicles are withdrawn from service for overhaul or repair; and

e) in the case of an application for a « B » licence, to the extent to which the applicant intends that the vehicles proposed to be used under the licence will be used for the carriage of goods for hire or reward.

Finally, if the Commissioners refuse to grant a licence, or grant a licence which

(*) From *Modern Transport*, 25th November and 2nd December 1933.

differs from the one applied for, or impose conditions to which the applicant does not agree, the Commissioners must, if requested, state in writing the reasons for their decision.

In the case of transport undertakings already in existence before the law was passed, it is laid down that :

If on an application for an « A » licence made not later than April 1, 1934, or such later date as the Minister may appoint, the applicant shows to the satisfaction of the Traffic Commissioner that during the year ended March 31, 1933, he used any goods vehicles belonging to him mainly for the purpose of the carriage of goods for hire or reward, the Commissioner must grant the application in respect of vehicles having an aggregate weight unladen not less than the aggregate weight unladen of any such vehicles so used by him at any one time during the said year.

Similar provisions apply in respect of an application for a « B » licence, but it is also laid down that the Traffic Commissioner must not attach any conditions thereto which would constitute a substantial interference with the carrying on of any trade or business for the purposes of which the vehicles were so used. Finally, the Act contains a sub-section dealing with vehicles engaged in contract work. If an applicant for an « A » licence satisfies the Traffic Commissioner that the vehicles will be used exclusively for contract work during a continuous period of not less than one year, the Commissioner may grant the application, but such vehicles will cease to be « authorised » after the termination of the contract unless the licensing authority directs otherwise.

It will be a condition of every class of licence *a*) that the vehicles are maintained in a fit and serviceable condition; *b*) that any legal provision with respect to limits of speed and weight, laden and unladen, and the loading of goods vehicles are complied with; *c*) that Section 19 of the Road Traffic Act, 1930, with respect to the time for which drivers of certain vehicles may remain continuously on duty and the hours which they are to have for rest are observed; and *d*) that the provisions of the Act relating to the keeping of records are complied with. Moreover, it will be a condition of an « A » and « B » licence that fair wages and proper conditions of employment shall obtain so far as employees are concerned.

So far as « B » licences are concerned the Traffic Commissioners are not required to attach conditions thereto during the first currency period — *i.e.*, one year — but it is laid down that, when considering subsequent applications, the authorities may attach the following conditions : *a*) That the vehicles must be used only in a specified district or between specified places; *b*) that certain classes or descriptions of goods only shall be carried; *c*) that goods shall be carried only for specified persons; and *d*) such other conditions (not being conditions with respect to the rates to be charged) as the licensing authority may think fit to impose in the public interest and with a view to preventing uneconomic competition.

In order to enable those concerned to put forward their objections, the Traffic Commissioners are required to publish applications : (1) for an « A » or « B » licence; (2) for a variation of a licence by way of additional vehicles; (3) for an increase in the maximum number of vehicles and trailers specified; and (4) for a variation or extension of the district (or places) within which vehicles can

be operated under a « B » licence for the carriage of goods for hire or reward. The Commissioners' announcements must show « the time within which, and the manner in which, objections may be made to the grant of the application. » These requirements will not apply to an application (*a*) which the Commissioners are bound to grant; (*b*) for a licence to expire not later than the existing licence under which the vehicles to which the application relates are authorised to be used for the purposes of a business which the applicant has, or intends, to aquire; (*c*) as respects which the Commissioners are of opinion that, having regard to its trivial character, any opportunity should be given for objection; and (*d*) for a short-term licence, where the application has been made with reasonable expedition, and the demand for the use of the vehicles under the licence is urgent.

It will be the duty of the Commissioners to take into consideration any objections to an application which may be made by persons who are already providing facilities, whether — and this is the important part of the Section — by means of road transport *or any other kind of transport*, for the carriage of goods for hire or reward in the district (or between the places which the applicant intends to serve) on the ground that *suitable* transport facilities are, or if the application were granted would be, either generally or in respect of any particular type of vehicles, in excess of requirements. Objections may also be made on the ground that the conditions of a licence held by the applicant have not been complied with.

A licence may be revoked or suspended, in whole or in part, on the ground that any of the conditions attaching to the licence have not been complied with. If the holder so requests the Traffic Commissioner must hold a public inquiry before revoking or suspending the licence, and a written statement may be obtained of the grounds for the decision.

An applicant for the grant or variation of a licence, who is aggrieved by a decision of a Traffic Commissioner, or an objector who duly made an objection which the Commissioner was bound to take into consideration and is aggrieved by the latter's decision, or the holder of a licence who is aggrieved by its revocation or suspension, may appeal to an Appeal Tribunal to be established under the Act. This tribunal will consist of three members appointed by the Minister of Transport. They may require the attendance of witnesses, examine them on oath, and award such costs as they consider reasonable. In addition they may fix the fees to be paid in respect of appeal, but may remit the whole or part on the ground of the poverty of an applicant. The decision of the tribunal on an appeal will be final and binding on the Traffic Commissioner; and, finally, it is important to note that where a person, who has applied for a new licence in substitution for one in force at the date of his application, appeals to the tribunal, the existing licence will continue in force until the appeal has been disposed of — subject, of course, to the revocation or suspension provisions aforementioned.

One of the conditions of every class of licence is the keeping of records; and the Minister of Transport is required to consult with the Transport Advisory Council as to the form in which these particulars are to be kept. A clause is inserted in the Act that the Traffic Commissioners may dispense with the observance of this requirement either generally or as respects any particular ve-

hicle, or as respects the use of vehicles for any particular purpose. They *must*, however, grant this dispensation in the case of vehicles used in the business of agriculture or of a travelling showman, unless, for special reasons, they are satisfied the requirement is desirable. Now as to the records themselves; these must show :

a) as respects every person employed by him as a driver or statutory attendant of an authorised vehicle, the times at which that person commenced and ceased work, and particulars of his intervals of rest and the like information as respects hinmself when acting as such a driver or attendant;

b) as respects every journey of a vehicle on which goods are carried under the licence, particulars of the journey and of the greatest weight of goods carried by the vehicle at any one time during the period to which the record relates and the description and destination of the goods carried; and the regulations may make provision for requiring drivers to carry and fill up the necessary documents.

The Minister of Transport is empowered to make regulations for carrying out the provisions of the enactment, particularly in connection with the forms to be used and the particulars to be furnished, the procedure on applications in connection with licences, the means by which vehicles are to be identified, whether by plates, marks or otherwise, as being authorised vehicles, and the custody, production, return and cancellation of licences, documents and plates. Before making regulations the Minister is required to consult with the various representative organisations, and, when made, the particulars must be laid before both Houses of Parliament.

Second part.

Clause 37, the most important in the second part, gives the Railway Companies the right to make agreements with firms for the transport at an agreed charge of all or part of their goods. The only condition is the approval of the Rates Tribunal, which will not be given if the object in view can be attained by an appropriate special rate applied in accordance with the 1921 Act.

The agreed charge must be submitted to the Tribunal which will publish it. Any firm considering it prejudicial to their business can put forward its objection. It can obtain a similar charge for the transport of its goods or of certain given goods on the same or another railway.

The Tribunal fixes the time the particular agreement shall remain valid.

In the case of opposition, it takes into consideration :

a) the net revenue of the Company;

b) the business position of the objector.

Arrangements have also been made to safeguard the interests of authorities or firms owning or operating ports and docks.

The regulations about publishing rates do not apply to particular agreements. These are, however, communicated to the Minister who must record them so that they can be consulted free of charge by anyone at the place and time stipulated by the Tribunal.

Clause 39 regulates the procedure to be followed in revising particular agreements when opposed by persons engaged in the coastwise shipping business.

Clause 40 dispenses the Companies from submitting for approval special new rates less than 5 % below the usual rates,

or restoring a special rate to an amount within the same limits.

In addition to this, other clauses in the second part lighten the obligations of the Companies in the matter of obtaining ministerial authorisation for opening new lines, electrifying lines, etc... the regulations applying to level crossing gates, the information to be supplied to the Minister of Transport in case of accident, and the formalities in the case of starting or giving up road transport services.

Third part.

General.

The main object of this third part is an interesting innovation. This is the creation of a Transport Advisory Council.

The object of this Council is to supply information to the Minister of Transport and aid him in his task of co-ordinating, improving and developing transport methods.

It consists of 29 members representing the different interests concerned, with a maximum of 3 additional members. The 29 members nominated by the Minister after consultation with the bodies or associations concerned, are made up as follows :

Interests.	Number of Representatives.
Local authorities in England and Wales	4
Local authorities in Scotland	2
Users of mechanically propelled vehicles	5
Users of horses and horse-drawn vehicles	1
Users of roads other than as above mentioned :	
Pedestrians	1
Pedal cyclists	1
Railways	3
Canals (other than canals owned or controlled by a railway company)	1
Coastwise shipping	2
Harbours and docks (other than harbours and docks owned or controlled by a railway company)	1
Labour	3
Trading interests (including agriculture	5

The Minister nominates the president from these members and also appoints one of the staff of the Ministry to act as secretary.

For the purpose of the proper discharge of its functions, the Council has the power to write to anyone for returns or information; it can also call upon anyone to attend as a witness or to give evidence or produce documents, in which case it pays his expenses. Should he refuse to appear, he shall be liable to a fine.

[624 .63 (.493)]

Some reinforced concrete structures on the Belgian National Railways,

by R. DESPRETS,
Professor at the University of Brussels,
Chief of the Bridges Designing Office of the Belgian National Railways Company.

This paper contains a brief description with drawings and photographs, of some reinforced concrete structures built in recent years on the Belgian Railways either on new lines or to replace level crossings.

These bridges have been designed in collaboration with the engineers, Messrs. Degreef, Clément, and Deryckere, and the heads of the drawing office, Messrs. Doison and Lebon.

Whilst retaining the simplest forms and those easiest to realise on the job, full advantage has been taken of the « Mechanics of Construction » by improving the form of the parts and of the structures as a whole.

* * *

Plain girder road carrying bridges.

Bridges with plain main girders of various design have been built in a number of cases for carrying roads over the railway lines.

Reinforced concrete has been adopted in preference to steel as being cheaper in first cost, requiring less attention, and as having more resistance to the corrosive action of locomotive fumes. If this latter property is to be secured, the reinforcement must be thoroughly well embedded and be a sufficient and constant distance from the shuttering.

These reinforced concrete bridges are of several types :

a) Bridges carried on concrete abutments, or

b) On intermediate supports on simple or crutched piers.

The bridge on concrete abutments usually is more costly than when intermediate supports are provided. Sometimes, however, intermediate supports are difficult to fit in with the lines and ordinary solid abutments have to be used. The abutments can always be much lightened, and by providing only the minimum reinforcement needed to bind the whole structure together, the concrete retains its « not reinforced » character.

With intermediate supports, the centre span is reserved for the main line, the two empty side spans being used to slope off the sides of the cutting or the embankment.

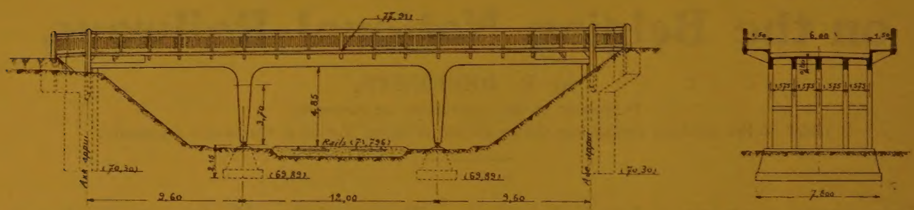
If provision is to be made for future new lines under the bridge, the side spans are designed so that they can be opened out without interfering with road traffic over the bridge (overbridge at Hoevenen — Antwerp North Station).

The intermediate supports are either simple piers or are in the form of crutches. Although the latter is better theoretically, it is open to question whether

Plate 1. — Plain girder bridges.

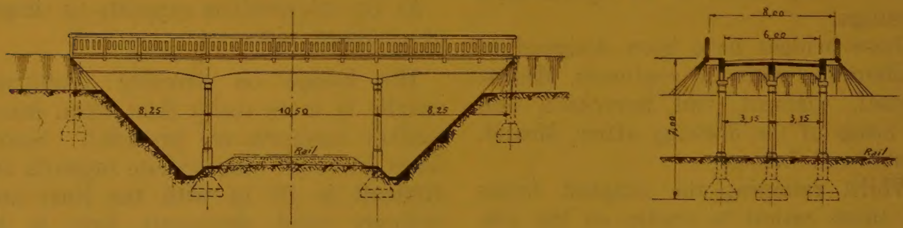
Uccle bridge (1927). — Schaerbeek-Hal line.

Elevation. Cross section.



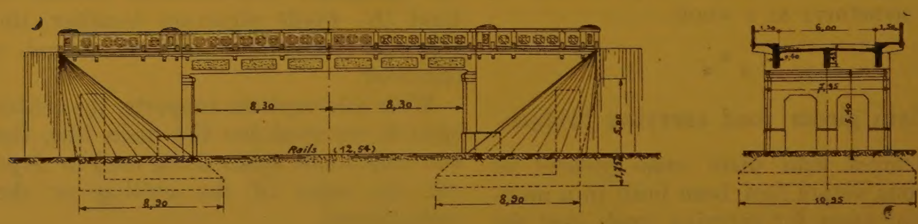
Anderlecht bridge (1925). — Brussels (Midi)-Ghent (St Peter) line.

Elevation. Cross section.



Road bridge on lightened abutments, 1934.

Elevation. Cross section.



the material benefit due to lightening the stresses in the girders makes up for the greater stress in the uprights. These latter when made in crutch form are more difficult to reinforce and to connect to the girders. Seemingly, in ordinary cases of average spans, simple intermediate piers, which are cheaper and more easily made, can be used. Many such bridges have been built, especially when building the Brussels-Midi to Ghent-St. Peter line.

* * *

Bow string girder bridges.

A cheap solution for a road bridge over railway lines, 35 to 40 m. (115 to 130 feet) span, is to use bow string girders.

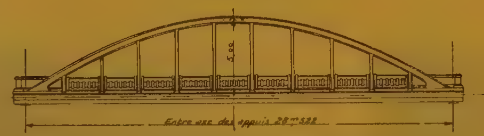
Photo 1. — Rue de la Procession road bridge, at Uccle. — Schaerbeek-Hal line.

Photo 2. — Hoevenen over-bridge. Antwerp North Station.

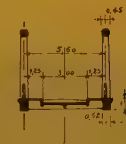
PLATE 2. — Over-bridges with bow string main girders.

Bridge over the Dendre, at Ath (1921).

Elevation.

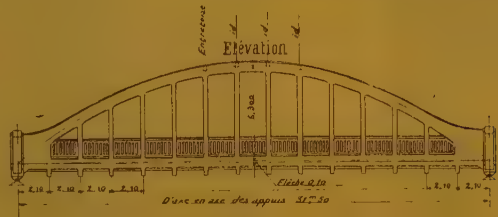


Cross section.

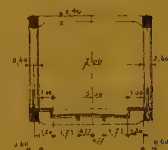


The Gouffre bridge, at Châtelineau (1928).

Elevation.



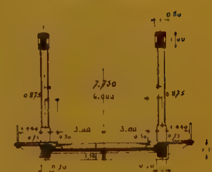
Cross section.



Rue de Pintamont bridge, at Ath (1931).

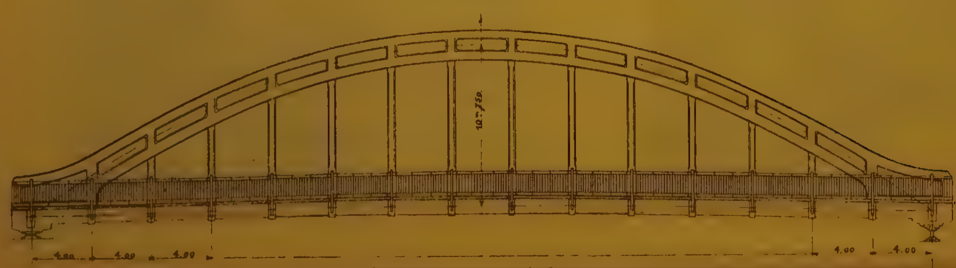
Elevation.

Cross section.

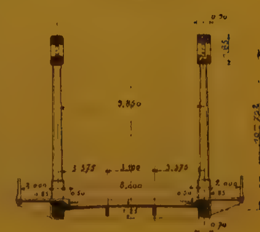


Chaussée de Bruxelles bridge, at Termonde (1932).

Elevation.



Cross section.



This girder is formed of a parabolic arch, tied by a tie beam in line with the edge of the flooring, the load due to this flooring being transferred to the arch through thin hangers.

The theoretical definition of this girder would correspond with that of a Vierendeel girder. In the latter, the uprights being subjected to bending would be splayed out where they join the arch and the tie beam; as a compensation the stresses in the arch and the tie beam due to dissymetrical overloading would be reduced. Briefly a bow string girder is the limit case of a Vierendeel girder the uprights of which are without stiffness.

Actually, the hangers having inertia in the plane of the girder are subjected to bending, and therefore may crack where fixed in the arch and the tie beam. In fact, such cracks do sometimes occur without, however, doing much harm to the structure.

As regards appearance, the thin hangers are better than the uprights of a Vierendeel girder.

The first bridges of this type were designed by Messrs. Considère of Paris, the arches being in hôoped concrete of octagonal section.

If it is true that the hooped octagonal section is the best under simple compression, this is no longer the case when the bending under dissymetrical overloading and the transverse rigidity of the arch are taken into account.

This leads one to prefer a deep I section with wide flanges and a web, plain or lightened (Ath and Termonde bridges).

Another essential feature of these girders is the arrangement of the haunches where the reinforcements of the tie beams and the arch are joined together in a solid mass of concrete, the stresses in which are complicated to analyse. If fundamental principles are applied, the bars of the tie beam must be anchored some distance beyond the theoretical centre line of the bearing.

This condition, if litterally followed, means a complicated reinforcement very difficult to complete and concrete satisfactorily. The joint strap bars which have to be provided near the bearings still further complicate this part of the structure.

As Mr. Dumas stated in the *Annales des Ponts et Chaussées* (1931), the arch and tie beam bars can be joined together better and more logically in the form of an orthogonal system, corresponding to isostatic lines and with the end hooks amply proportioned. The problem is still further simplified if the bars are welded instead of using strapped joints. The limit of this method is reached when the arch and tie beam bars are made continuous. A footbridge now under construction on the Brussels-Antwerp line was designed on these lines.

Plate 2 reproduces different types of arches and shows the evolution from the octagonal to the lightened-out double T section. The most recent designs are those of the Ath and Termonde arches.

The Ath arch is very pleasing in appearance. The webs are hollowed out into open box sections.

The Termonde arch, the latest type, is lightened out between the uprights and, in consequence, is very light in appearance.

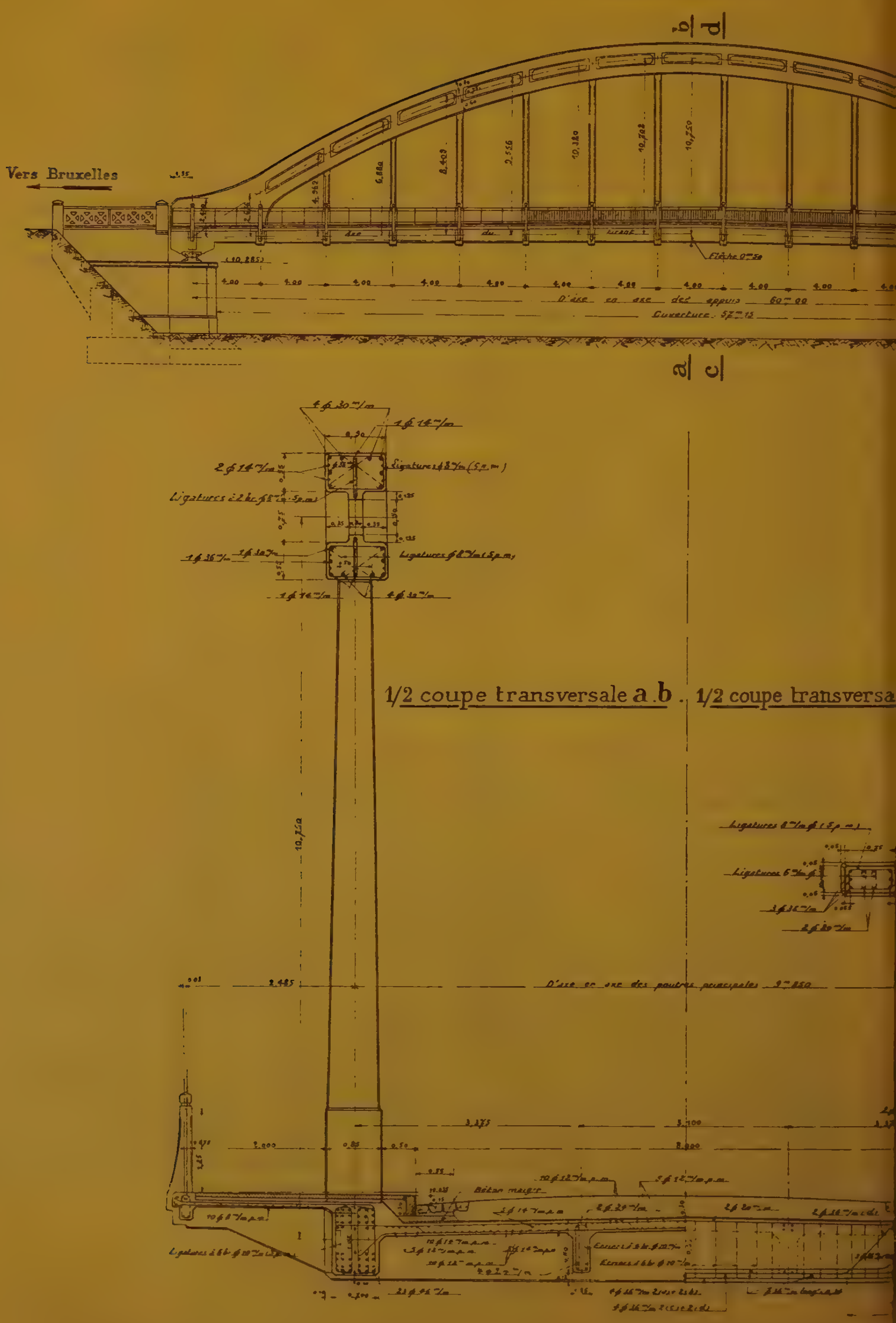
The Termonde over-bridge bow string girders have other special features. As already mentioned, the bars have been welded systematically for the first time in Belgium in the case of a reinforced concrete bridge.

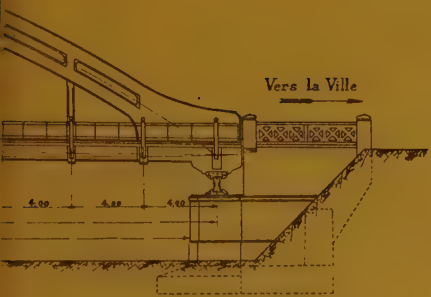
PLATE 3. — **Termonde station.**

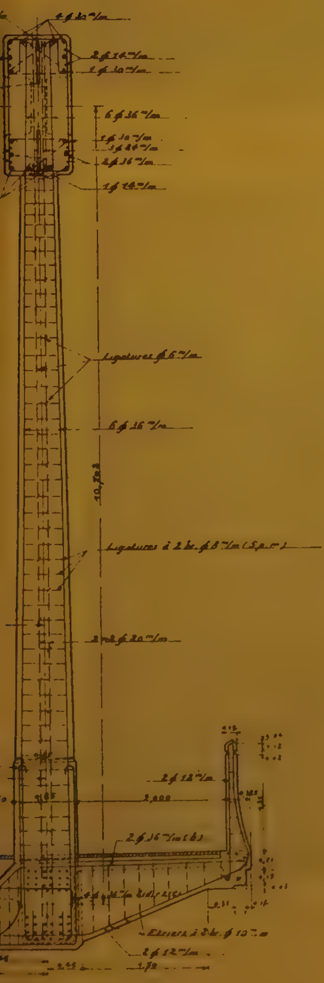
Overbridge replacing level crossing No. 60 on the Brussels

(Theoretical span: 60 m. = 197 feet.)

GENERAL ELEVATION.







Explanation of French terms:

Vers Bruxelles = To Brussels. — Vers la ville = To the town. — Axe du tirant = Centre line of stringer. — Flèche = Rise, — 1/2 coupe transversale *a b* = Half section *a b*. — Ligature = Binding wire. — D'axe en axe des appuis = Distance between centres of the bearings. — Ouverture = Span. — D'axe en axe des poutres principales = Distance between centres of the main girders. — Béton maigre = Poor concrete. — Etriers = Stirrups.

Electric arc welding does not weaken the bars in the arch in any way, according to the specifications of the Paris Chamber of Commerce for reinforced concrete.

The tie beam reinforcement has been designed on the principle of adding sufficient bars for making the joints whilst seeing the bars are cut up in a rational way. The safety of the structure was satisfactory even without welding the bars. The welds, by doing away with all discontinuity in the bars, automatically increases the strength by improving the way the stresses are transmitted.

Besides, the main advantage of welding seems to be, not so much the saving of metal or concrete, but the greater simplicity of the reinforcement as the bars do not overlap, and the safety and ease with which the concreting can be carried out and the reinforcement embedded in the concrete.

In this connection, the girders of the 60-m. (197-ft.) span Termonde bridge were very easily built and proved the reinforcement had been properly designed.

The absence of any cross bracing is one of the features of this bridge. The great transverse stiffness of the arch and the effective junction of the hangers — uprights of the girder — with the arch have made it unnecessary. This junction is obtained by the reinforcement — uprights — being of inverted crutch form at the ends of the girders.

Photo 3. — The Gouffre over-bridge at Châtelineau station.

Photo 4. — Termonde bridge. — Reinforcement of an end haunch block.

Photo 5. — Ath over-bridge — replacing a level crossing.

At a later date we intend to deal with the buckling resistances of the arches of these girders. It may be stated that experience has shown that the design of the Termonde bridge can be used on bridges of greater span.

The way the abutments have been built up should be noted. Each abutment consists of two main pillars carrying the bearings, connected under the bearings, and to the foundation by two cross bearing slabs forming a closed frame.

The fill can spread itself freely between the main bearing pillars.

These pillars, owing to the foundation slab, can rest directly on the soil or be carried on piles.

The Termonde bridge bearings are made of cast steel. The mobile part is merely a rocker between upper and lower bearings.

An interesting innovation was incorporated in the Ath, Manage, and Charleroi over-bridges. Bearings entirely of reinforced concrete were used in place of the usual metal bearings with rollers. The new design of mobile part consists of a concrete rocker reinforced by transverse bars in layers. The top and bottom bearing surfaces are curved. To prevent local crushing through the contact surfaces being irregular, thin sheets of antimony lead are inserted between the bearings and the rocker. These rockers were easily and cheaply made. The contact surfaces were actually so good that the lead sheet was really not needed.

The general view of the complete structure taking the place of the Ath level crossing is also given. The thin flooring with straight girders has been carried out with encased beams.

* * *

Footbridges.

A number of reinforced concrete footbridges have been built since 1922, most

Photo 6. — Termonde over-bridge — replacing a level crossing.

Photo 7. — Termonde over-bridge.

of them with light bow string girders. The oldest, over Liége-Guillemins Station, consists of two 40-m. (131-ft.) spans on an intermediate lightened pier. The arches are polygonal, generally following a parabola.

They would have looked better had they been designed wholly parabolic. The arch and tie beams have practically a double T with open box form section.

The Herbatte footbridge, at Namur, has a centre span with bow string girders and two side straight girder spans.

More recently, a much lighter construction was aimed at and obtained on the Athus footbridge, and those under construction on the Brussels-Antwerp line.

In these latter footbridges the bearings were made in an ingenious and also cheap manner by articulating one of the bearing pillars so as to make it into a rocker of considerable height.

The joints were realised by plain cross sections connected by plain straight rods.

The reinforcement of the arch and the tie beam of the footbridges being built over the Brussels-Antwerp line are welded together so that continuity of the bars of the arch and those of the tie beams is obtained.

All these footbridges are cross braced at the top.

As an example of a footbridge with straight girders, the Cornillon footbridge at Liége, over the Liége-Visé line, may be mentioned. In cross section the foot bridge is a single web T, the foot passengers walking on the horizontal slab.

* * *

Arch bridges.

In an earlier note, we dealt with different designs of arches built in concrete or reinforced concrete (1). So far few reinforced concrete road bridges on arches with light small columns have been built on the Belgian National Railways.

In 1933, however, an over-bridge of

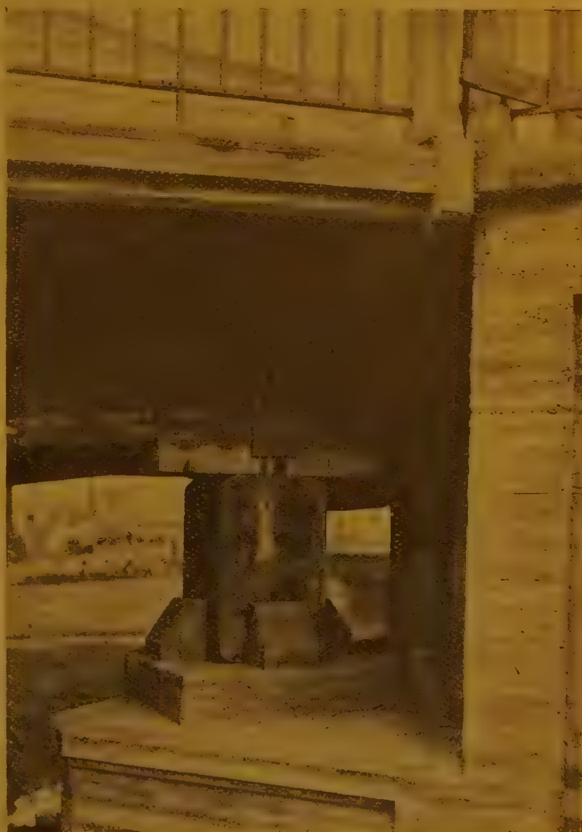


Photo 8. — Ath over-bridge. — Mobile bearing.

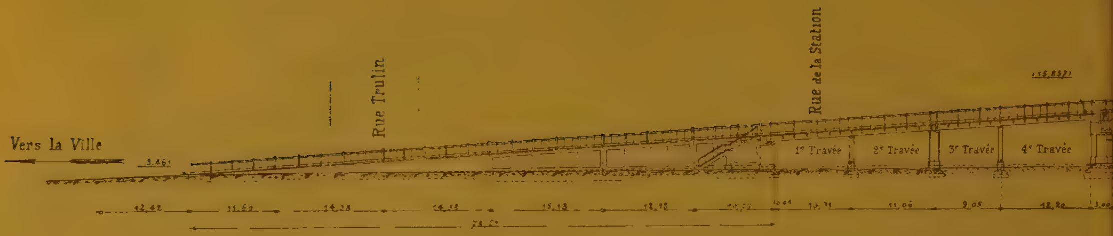
this kind was built over the Mont-Saint-Guibert cut.

The articulated joints of the arches are plain cross sections connected by

(1) See *Bulletin of the International Railway Congress Association*, April 1933.

PLATE 4. —

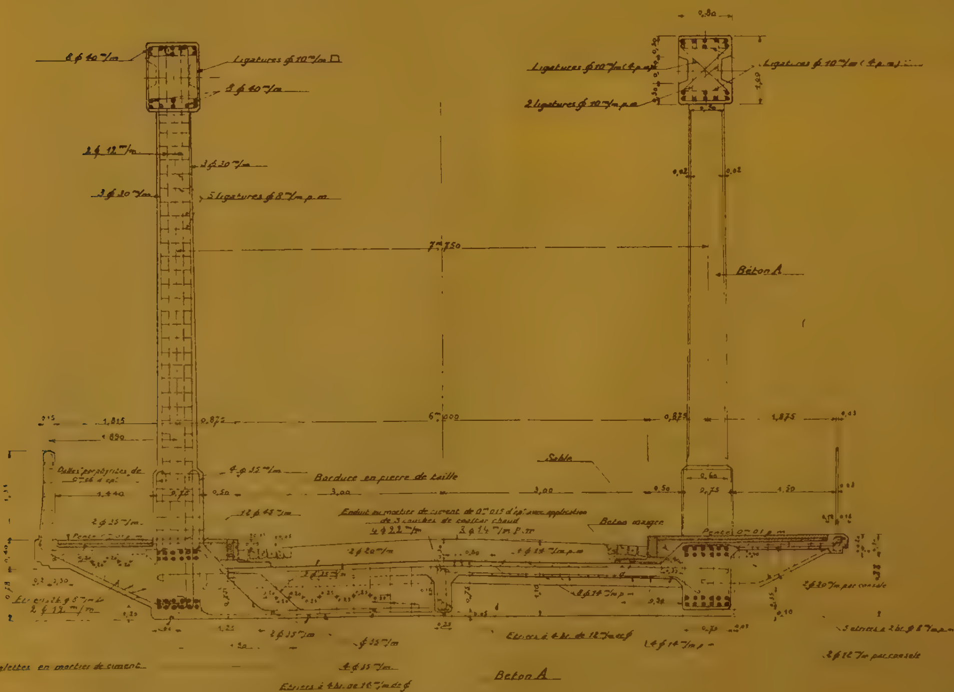
Suppression of the Pint
General elevation of the



Fifth bay. — Theoretical span 43.42 m. (142 1/2 feet).

Half cross section on centre line of an upright.

Half cross section on centre line of a panel.



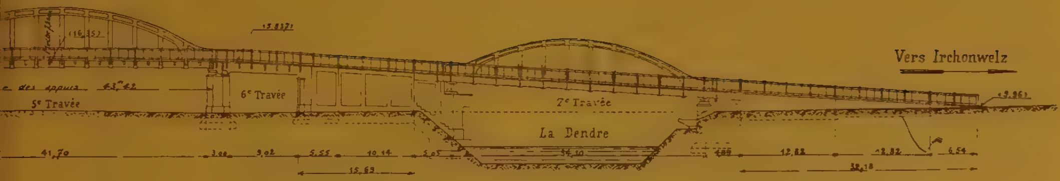
Explanation of French terms:

Ligatures = Binding wires. — Dalles porphyrites = Porphyrite slabs. — Pente = Gradient. — Etrier = Stirrup. — Réglettes en mortier de ciment = Levelling strips in cement mortar. — Bordure en pierre de taille = Dressed ashlar curb. — Couches de coaltar chaud = Layers of coal tar applied hot. — Béton A = A concrete. — Béton maigre = Poor concrete. — Par console = Per bracket.

ation.

d level crossing.

(Lessines side).



Explanation of French terms:

Vers la ville = To the town. — Vers Irchonwelz = To Irchonwelz. — Travée = Bay. — Flèche = Rise. — D'axe en axe des appuis = Distance between centres of bearings. — La Dendre = River Dendre.

straight bars at the crown and at the springings. These joints are in fact cuts to meet any possible settlement in the sands met with in the cut.

The high small columns of the spandrels are also cut at the connection with the arch and the flooring to avoid any trouble through being fixed.

The centre part is flanked by two massive pillars which form the transition from the arch to the light lateral spans with plain girders.

The abutments in the cut are lightened considerably.

* * *

Retaining walls.

Most previous retaining walls were built to full section in bricks or concrete. In some cases of considerable height, the wall was lightened by making it a blind viaduct in masonry, the earth being able to move freely over the natural slope inside the arches, the surface of which was protected by a reinforced concrete facing. Walls of this type were built at Alost and Buysinghen (the latter on the Schaerbeek-Hal line).

The results of an application made before the War, of reinforced concrete walls, were unfavourable as the walls were not properly designed. When reconsidered in connection with the heavy programme of works the Belgian Railways had to carry through, the problem was successfully solved for several profiles.

In its simplest form the profile is a T square with the vertical wall (stem) holding back the ground, and a base slab. The base slab is embedded in the ground, only the wall being left visible. It consists of a back slab taking the load of the counterbalancing weight of the earth and a forward projection giving the necessary extension to distribute the pressure over the ground properly.

The stem generally has a slight batter on both faces so as to improve the section as it approches the foundation slab.

This wall shape is very economical and has been used up to 3 m. (9 ft. 10 in.) high.

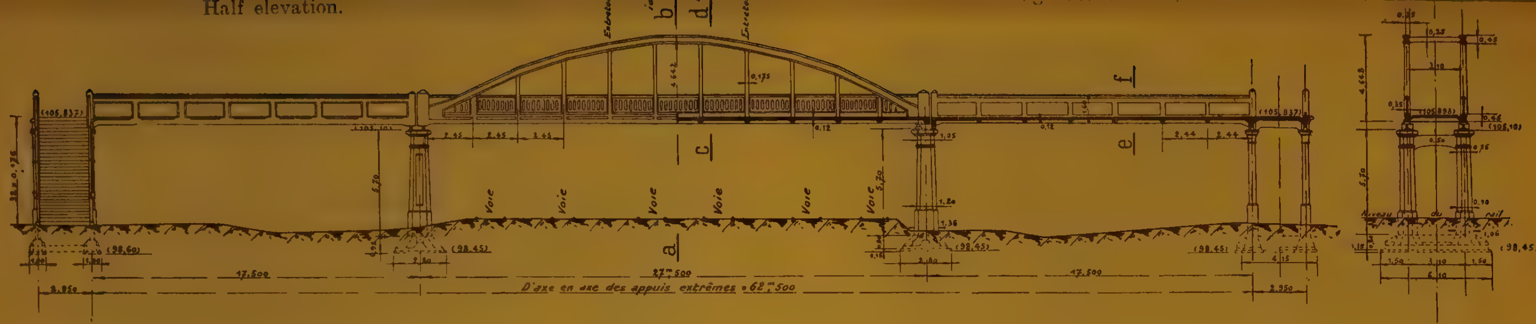
When the depth of the cut increases it is cheaper to lighten the full section parts and modify the section on the usual lines of reinforced construction with thin slabs and ribbed girders.

The reinforcement of the usual shape

Photo 9. — Ath station. — Suppression of level crossing.

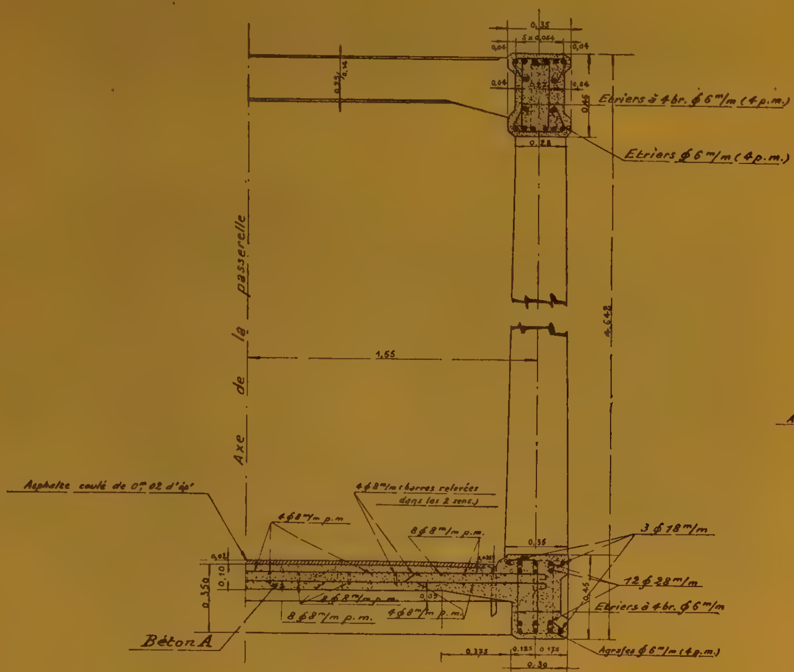
Photo 10. — Footbridge over Liége-Guillemins station.

Half elevation.



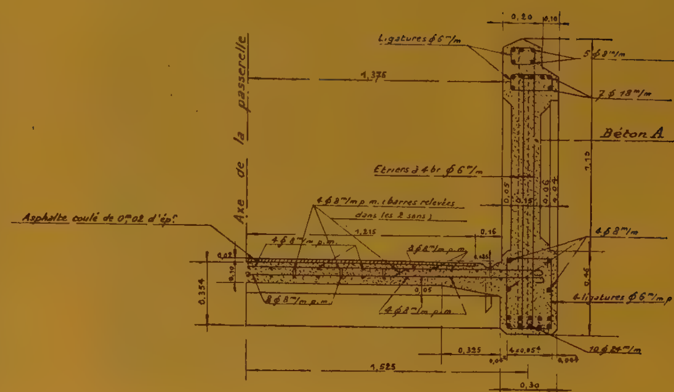
Middle bay.

Half section on *c d.*



End bay.

Half section on *e f.*

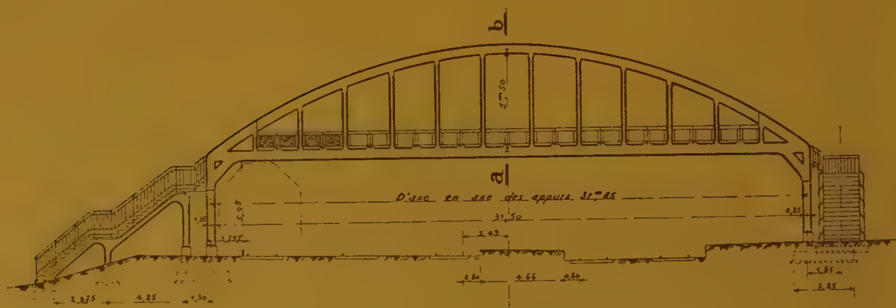


Explanation of French terms:

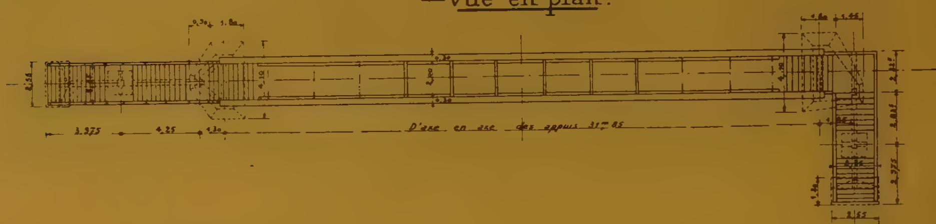
Entretoise = Cross tie. = Voie = Track. — Niveau du rail = Rail level. — D'axe en axe des appuis extrêmes = Distance between centres of outer bearings. — Etriers = Stirrups. — Axe de la passerelle = Footbridge centre line. — Asphalte coulé = Molten asphalt. — Barres relevées dans les 2 sens = Bars raised in both directions. — Béton A = A concrete. — Agrafes = Clips.

Plate 6. — Athus station — Footbridge.
(Theoretical span 31.85 m. = 104 1/2 feet).

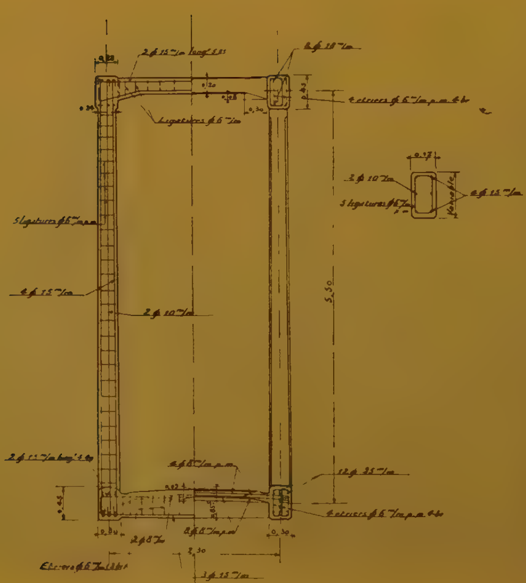
Elevation.



—Vue en plan—



Section on *a b*.



now used consists of counterforts with horizontal connecting girders — shelf edge, end girders of the base slab — connected together vertically by a thin wall and horizontally by a foundation block.

In the earlier examples the vertical side was stiffened by orthogonal ribs breaking it up into squares (most economical form of slab).

Owing to the difficult shuttering, the wall with plain surface on the earth side is preferred.

The counterforts are about 3 m. (9 ft. 10 in.) apart. They complicate the shuttering as well as the reinforcement. For economy the T shape of maximum height should be used when possible, the counterforts becoming merely wall stiffeners.

Walls of this design which are much cheaper than plain or arcaded walls

Photo 11. — Athus station footbridge.

Photo 12. — Athus station footbridge.

Photo 13. — Athus station footbridge.
Mobile pier.

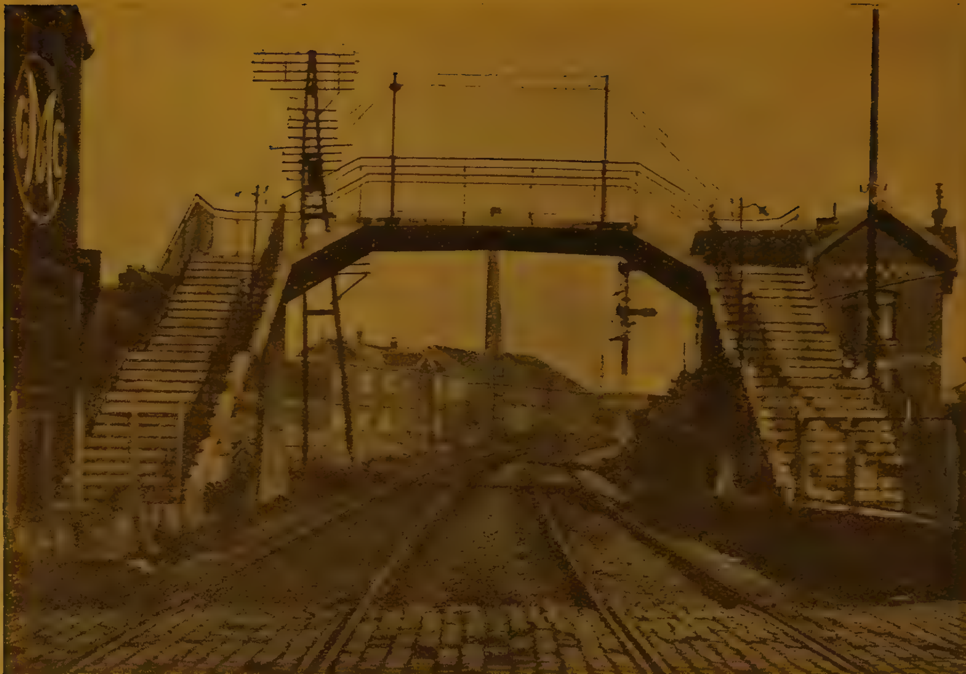
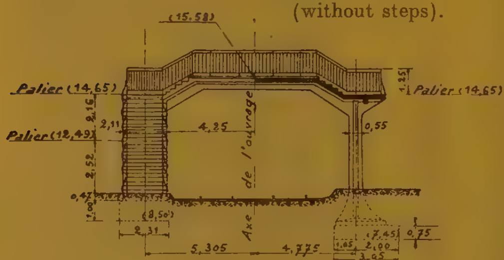


Photo 14. — Cornillon (Liége) footbridge.

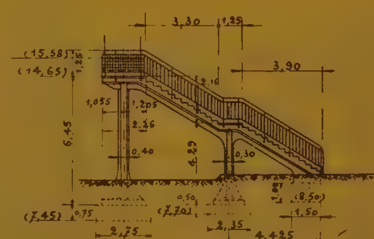
Plate 7. — **Liége-Visé line. — Cornillon station.**

Footbridge at level crossing.

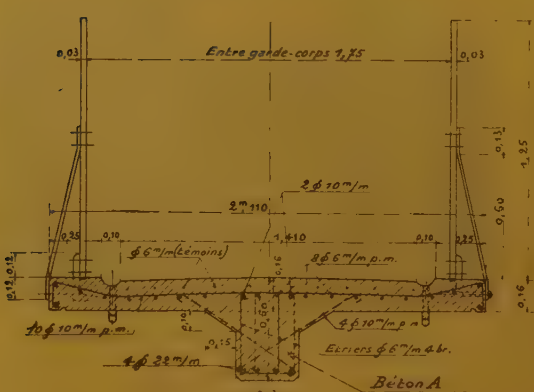
Half elevation. Half cross section. (without steps).



Side view.



Cross section.



Explanation of French terms:

Palier = Landing. — Entre garde-corps = Between hand rails. — Ø 6 m/m (témoins) = 1/4 inch bars (limits). — Etriers = Stirrups. — Beton A = A concrete.

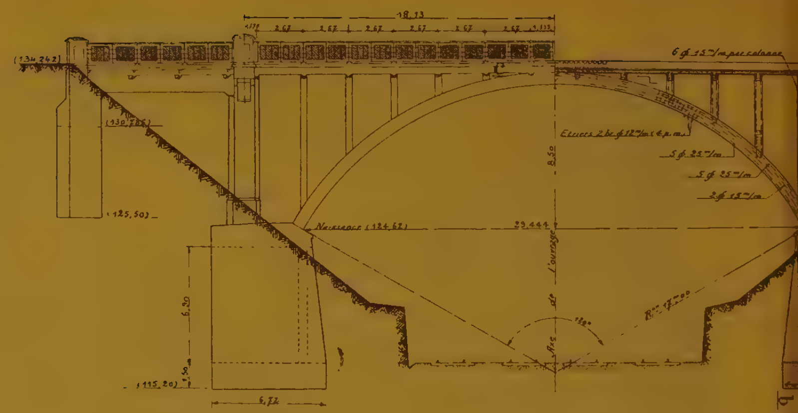
Mont-Saint-Guibert overbridge.

Photo 15. — General elevation.

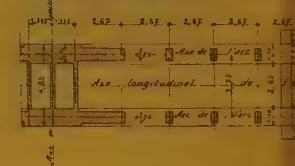
Photo 16. — Side view.

Half elevation.

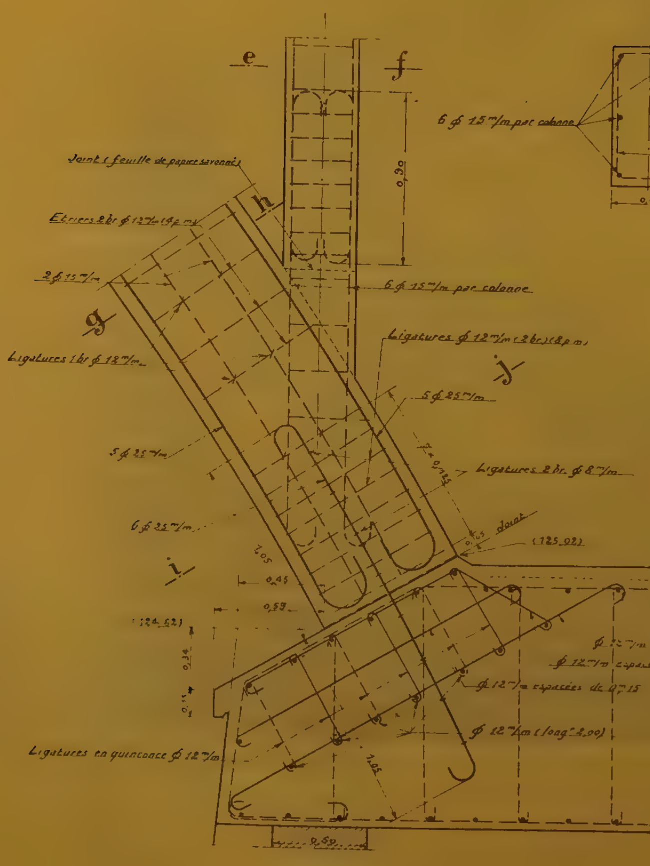
Half section on lo



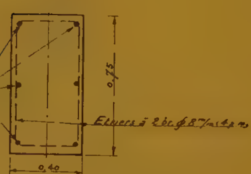
— Coupe horizontale suivt

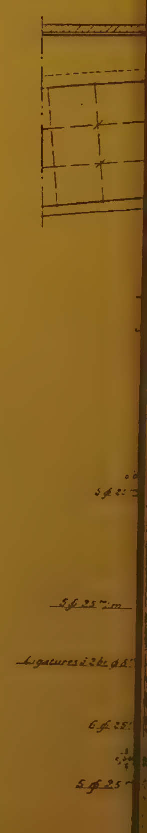


Hinge at the springings.



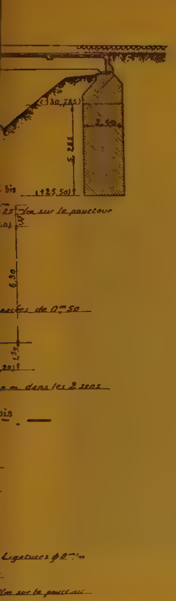
Section on e. f.



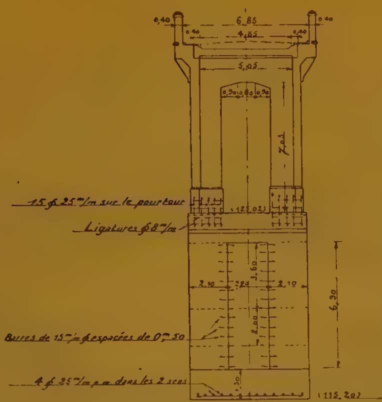


...uibert overbridge.

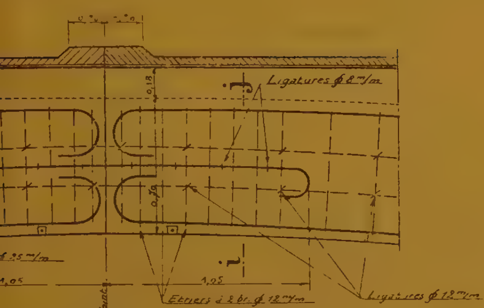
...re line of the structure.



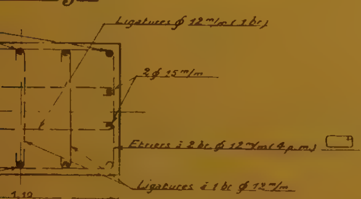
Elevation along a, b.
(road surfacing removed)



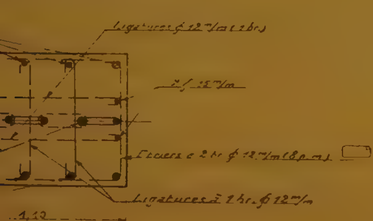
...Hinge at the crown.



...suivt g.h.—



...suivt i.j.—



Explanation of French terms:

Naissance = Springing. — Axe de l'ouvrage = Centre line of the structure. — Etriers = Stirrups. — Par colonne = Per column. — Sur le pourtour = On the whole circumference. — Barres de 15 mm. espacées de 0.50 m. = 15-mm. bars spaced 0.50-m. çentres. — Dans les 2 sens = In both directions. — Ligatures = Binding wires. — Coupe horizontale suivt c c^{bis}, d d^{bis} = Horizontal section along c c^{bis}, d d^{bis}. — Axe longitudinal de l'ouvrage = Longitudinal centre line of the structure. — Joint (feuille de papier savonné) = Joint (soaped paper). — Ligatures en quinconce = Binding wire in quincunx. — Variable = Varying. — A la clef = At the crown. — Aux naissances = At the springings.

Photo 17. — Schaerbeek-Hal line. — Beersel over-bridge.

have been built on ground of poor consistency on which the older types would have required expensive foundations on piles.

Ample room must be provided for the haunch block. When the filling follows the building of the wall this condition is easily met.

In some cases the sides of a narrow and fairly deep trench are to be held up, as for example when carrying a line under a station (Brussels-Tervueren line under the Etterbeek station) or when making access roads to a subway on the centre line of a road between houses.

In this event it is hardly possible to arrange the counterweight blocks to equalise the ground thrust. To balance this latter, interior forces have to be brought into play.

A solution is to build a vertical retaining wall on both sides to hold up the ground supported by reinforced concrete frames open at the top to form a U or framed together. This method is used when it is expensive to provide the blocks and the distance between the walls is small enough for the squaring up of the U's or frames not to be too troublesome.

When instead of a trench an approach road to an overbridge has to be built on a road with houses on both sides, there is no difficulty in placing the blocks inside the embankment. However, if the approach road is narrow (30 to 40 feet, for example) the ordinary solution can be modified satisfactorily by only retaining the vertical retaining walls stiffened by vertical uprights and cross-tied through the embankment by hinged flexible ties taking the thrusts. This method is much cheaper than the ordinary wall with block (construction of approach roads to overbridge at Ath and Manage).

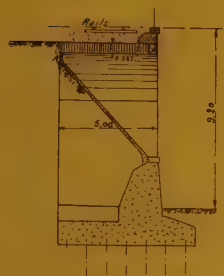
The general recommendation when building reinforced concrete walls to make provision for relatively closely spaced expansion and contraction joints should be kept in mind. Generally speak-

Plate 9.

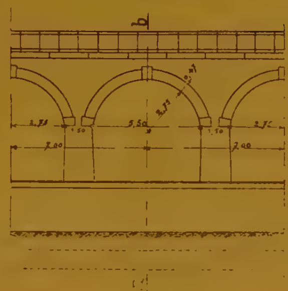
Schaerbeek-Hal line. — Arcaded walls.

Full section.

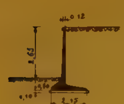
Section on *a-b*.



Part elevation.

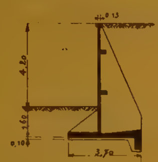


T. (cantilever) design.
Malines.

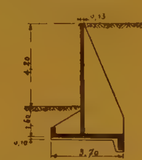


Design with counterforts.

Brussels-Midi.

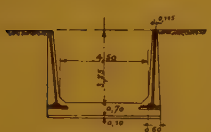


Malines.

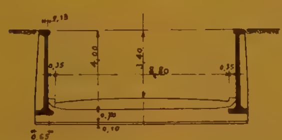


U counterforts.

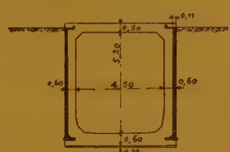
Etterbeek.



Houdeng-Goegnies.

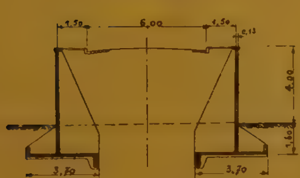


Frame counterforts.
Etterbeek.

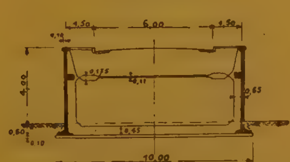


Road between walls designed with counterforts.

Usual design.



Screens with tie beams.
Ath and Manage.



ing, these walls are built in sections of 4 to 5 panels between joints (with counterforts near them). Experience has proved that expansion joints arranged in this way are both efficient and necessary.

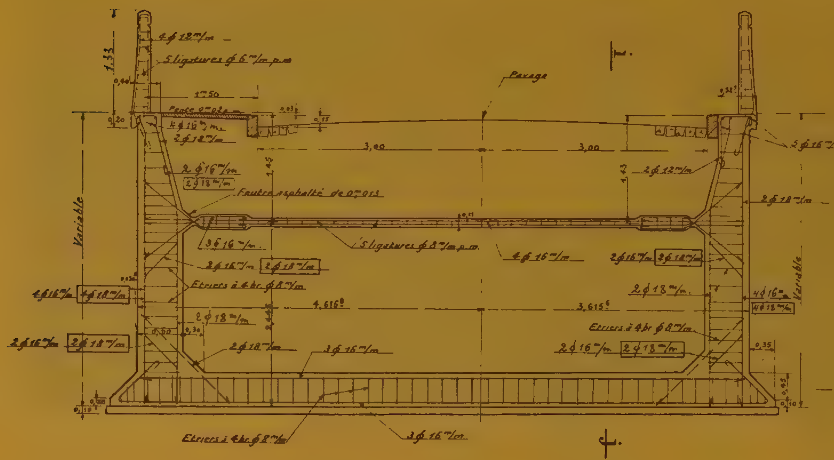
Reinforced concrete tubes.

This term is applied to structures of limited opening, of square or rectangular form, free from obstructions.

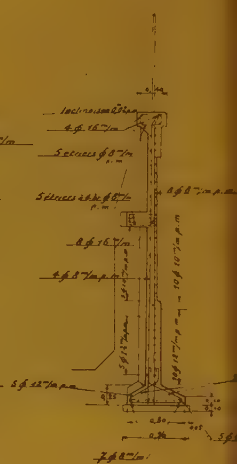
PLATE 10. — Ath station. — Suppression of the Pintamont street level crossing

Retaining walls of the approaches to the bridge over the railway.

Cross section on centre line of an end counterfort.

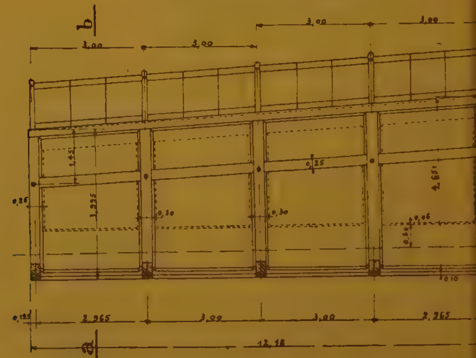


Section on *a b*.

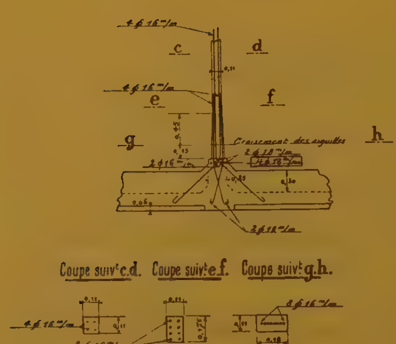


N.B. Les armatures principales des contreforts intermédiaires ont 18 m/m de diamètre

Back elevation of a section on *i j*.

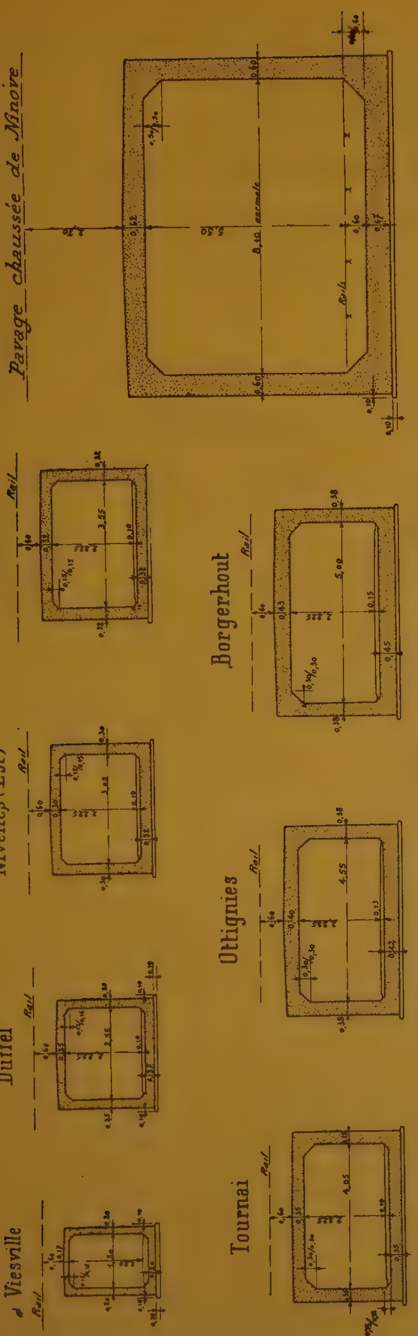


Details of tie beams.



Explanation of French terms:

Ligatures = Binding wires. — Pente = Gradient. — Feutre asphalté = Bitumised felt. — Etriers = Stirrups. — Inclinaison = Slope. — N. B... = The main reinforcements of the intermediate counterforts are 18 mm. in diameter. — Croisement des aiguilles = Crossing of needle bars.



Subways.

Note: Pavage... = Ninove road surface.

The walls of the section consist of relatively thin slabs without stiffening ribs.

Many structures of this kind have been built since the War, either as culverts or small subways. A skew bridge for a double track line was built some years ago in Schaerbeek station by using two tubes side by side, one for each track, on new fill, and the cost was low.

These structures include, in cross section, a foundation slab forming the floor, and designed on rational principles. They are especially suitable in poor soil. They are cheap when the free span is small enough to keep down the cost of the bottom supporting slab.

This type of structure has been widely used during recent years.

One of the most important was the double-track skew bridge where the new Brussels (Midi)-Ghent (St. Peter) line is carried over the Brussels-Ninove road.

By using a rectangular section with walls of uniform thickness there was no difficulty in making the very much skewed heads of this structure. The thin floor too made it possible, when excavating, to keep the under side of the foundation high enough to keep clear of the thick layer of quicksand immediately below it. This latter was the main reason why this type of structure was adopted.

Many subways under the track are further examples of the systematic use of this form of construction. Generally speaking these subways are 3 to 5 m. (10 to 16 1/2 feet) wide. The rectangular cross section with thin walls means cheaper foundations and reduces the depth of excavation under running lines to a minimum. The track can be supported during the construction on box girders, of low height or braced by rails.

[385. 587 (.493), 621. 138.5 (.493) & 625. 26 (.493)]

Reorganisation of the Malines main repair shops

(Belgian National Railways Company),

by A. VERBEEMEN, Engineer, Malines Works.

SECOND PART (1)

Locomotive repairs.

The programme of locomotive repairs at the main work shops at Malines provides for :

a) *heavy repairs* which include the thorough overhaul of the boiler, frame, motion, and wheels; and

b) *medium repairs* or a complete repair to the motion, spring gear, and running gear, including, when necessary, essential repairs to the boiler.

The stock of locomotives based on Malines for heavy repairs consists primarily of 0-6-0, 0-8-0, and 0-10-0 goods engines, and a class of 4-6-0 passenger engines with two outside cylinders.

The goods engines come in for heavy repairs on the average after 180 000 km. (111 850 miles) and the passenger engines after 240 000 to 300 000 km. (150 000 to 186 000 miles). These engines receive two, sometimes three, medium repairs between two heavy repairs.

Formerly, the medium repairs were carried out at the locomotive depots. They were progressively concentrated on a small number of shops specially equipped to deal with certain particular types. The fall in traffic, the greater distance run between heavy repairs, and the improved efficiency enabled us to set aside part of the main shops for medium repairs, although these shops originally were only intended for heavy repairs. Thus, the Malines main shops at the present time are carrying out medium repairs to eight-coupled goods engines and possibly in the future to other classes.

These workshops were designed to turn out at least one heavy and one medium repair per working day, i.e. to deal with 50 locomotives a month; at the present time they have to deal with only about half the number.

In the first part of this article we dealt with the principles on which the works were reorganised; before describing the equipment and repair methods it will be as well to describe briefly the modern principles of standardisation and working to limit gauges introduced at Malines.

I. — Standardisation.

The locomotive stock of the Belgian National Railways Company at the present time still includes 42 types of widely different design and origin. The problem of reorganising the works on a scientific basis was made extremely complicated by the immense variety of shapes, dimensions, and materials used on parts for the same purpose.

(1) The first part was published in the August 1934 issue of the *Bulletin of the International Railway Congress Association.*

Under such conditions, standardisation became of capital importance. It has been applied to the greatest possible extent to the materials used, to the shapes and dimensions of the parts, whilst at the same time care has been taken to design the standard detail to have the greatest strength and be easiest to machine.

Standard materials.

Most of the locomotives were built of dead soft mild steel both for the boiler and for the engine; parts subject to wear were case hardened and tempered.

At the present time, advantage is being taken of the different classes of carbon steel now available; the table below gives particulars of the classes of steel used and the main purposes :

Class.	Tensile strength kgr./mm² (*Engl. tons per sq. inch*).	Minimum elongation.	Principal use.
AS (Siemens-Martin)	35 to 40 (*22.2 to 25.4*)	30 %	Forgings. Case hardened parts. Flanged boiler plates.
BS (Siemens-Martin)	40 to 48 (*25.4 to 30.5*)	28 %	Rolled sections. Rivets. Bolts. Boiler plates.
C (plates not annealed)	38 to 44 (*24.1 to 27.9*)	20 %	Smoke box plates (only having to resist corrosion).
D	44 to 52 (*27.9 to 33.0*)	24 %	Carriage and wagon frames.
ES (Siemens-Martin)	55 to 62 (*34.9 to 39.4*)	20 %	Locomotive motion parts.
GS (Siemens-Martin)	70 to 78 (*44.4 to 49.5*)	15 %	Locomotive parts subjected to friction.

Parts manufactured in ES steel (rods, piston rods, motion levers and links, spring hangers, equalising levers and spring links, drawgear details, brake shafts, cranks and crank pins) and in GS steel (slide bars, motion quadrant links, axlebox wedges, buffers and buffer plates) are suitably heat treated (annealed, hardened, tempered).

The bronzes and white metals have been reduced to the three following classes :

Bronzes.	Composition.					Use.
Class.	Copper.	Tin.	Lead.	Zinc.	Phosphor.	
B 1	79.8	10	10	—	0.2	Brasses not white metal lined.
B 2	90	6	—	4	—	Fittings. White metalled brasses.
B 3	81	11	—	7.7	0.3	Axle box brasses, slide valves, motion bushes.

White metals. Class.	Composition.				Use.
	Tin.	Lead.	Antimony.	Copper.	
M 1	83	—	11	6	Bearings of express locomotives and bogie carriages.
M 2	60	23	11	6	Locomotive bearings.
M 3	—	80	20	—	Ordinary carriage and wagon bearings.

The cast steels and cast irons have been standardised on the same lines.

Standardisation of shapes. — This standardisation was applied in particular to :

a) fork joints in the motion, brake and spring gear: all such joints are now bushed, the bushes being hard bronze in the former and case hardened mild steel in the others.

b) dead soft mild steel case hardened and heat treated was selected for the different pins (motion, spring gear, brake, etc.) the pins working in bushes and being pinned through.

c) brake beam ends are case hardened and tempered, and work in bushes held by split pins.

d) bronze bearings for axle boxes and hard bronze axle box flange lining plates.

The tapers of conical fits, of rod end wedges, and keys have also been standardised.

Standardisation of dimensions and working to limit gauges. — As the engines widely differed in design, the dimensions, for example, the diameter of such parts as knuckle joints, holes in units, etc..., varied considerably ; lists of standard diameters were prepared and must be followed in all the shops on the system.

As the result of using bushes everywhere, all pin joints in the motion, brake and spring gears are restored to the drawing dimensions when the engine is repaired. This method has great advantages : the bushes and pins are manufactured in the automatic turret lathe section beforehand to meet stores requirements according to the expected programme. In addition all turning and boring is done to *limit gauges.*

The system of tolerances adopted is that of the Belgian Standardisation Association (A.B.S.). Plate VIII shows the types and qualities of fits under this system of tolerances under two sub-systems: *standard holes*, and *standard pins.*

The *standard hole* sub-system has been adopted for repairs to locomotives. The diameter of the holes is consequently kept constant, of course within the allowed limits, and the diameter of the pin is adjusted to suit the part to which it belongs and the type of fit specified. This method is the cheaper for the usual fitting ; one reamer meets all requirements for a given degree of finish, whatever play or shrinkage be used.

In locomotive repair work « *perfect* » and « *accurate* » fits are little used ; the « *careful* » fit is usually employed for motion parts ; it is the best where a fork joint is fitted with bronze bushes, both for boring out the part and the bush.

The « *ordinary* » finish meets requirements for the spring and brake gear in most cases.

The « *turning* » fit T3 is used for the motion parts and cylinders. Table 1 gives

the play for the bore of the bush and the diameter of the pin, as well as the maximum and minimum play between the bush and the pin.

In the case of the brake fittings and spring gear, the use of the « *ordinary* » quality of finish (A4) with the free turning fit L4 would give too little minimum play in the small diameters. The sliding fit G4 has been used therefore and the normal diameter of the pin has been reduced by 0.5 mm. (0.0197 inch).

TABLE I.

Gauges for pins and bushes of valve gear and motion work.

Quality 3 : « Careful fit »

Nominal diameter.		Bore (bush).		Pin.		Play.	
above... millimetres.	up to... millimetres.	A3 (microns).		Turning fit. T3 (microns).		minimum (microns).	maximum (microns).
10	18	0	+ 35	— 15	— 50	15	85
18	30	0	+ 45	— 22	— 70	22	115
30	50	0	+ 50	— 25	— 80	25	130
50	60	0	+ 60	— 30	— 100	30	160
60	70	0	+ 60	— 30	— 100	30	160
70	80	0	+ 60	— 30	— 100	30	160
80	90	0	+ 70	— 35	— 120	35	190
90	100	0	+ 70	— 35	— 120	35	190
100	110	0	+ 70	— 35	— 120	35	190
110	120	0	+ 70	— 35	— 120	35	190
120	180	0	+ 80	— 40	— 140	40	220

There are other cases in which the A. B. S. system has had to be departed from and the tolerances this system allows have been applied starting from a somewhat higher or lower diameter.

In the case of pins the quality « *Careful* » can be obtained on a good lathe, but the quality « *Accurate* » means an expensive finish. Now the A.B.S. system does not provide for « *Careful* » finish for fixed assemblages such as bushes pressed into plain ends or forked joints; in such a case the « *Careful* » finish A3 has been adopted for boring out the plain end, and for turning up the bush the « *Sliding* » finish G3 but with the nominal diameter increased by an amount which varies with the diameter, so as to have the minimum grip required without exceeding the amount which would prevent the bush being pressed into the plain end, or would set up excessive stresses therein; this type of fit is known as the G3 pr. (G3 pressed). Table II gives the additions to the diameters provided for and the maximum and minimum grip for each set of nominal diameters.

Synoptical table of class and type of fits.

SYSTEM OF TOLERANCES

A. B. S. 24.03

Sub-sections.

Standard bore.			Standard pin.	
Bore independent of the type of fit.	Pins dependent on the type of fit.		Bores depending on type of fit.	Pin independent on the type of fit.

Quality 1. PERFECT. Blue gauges.

Bore	Pins	Fit	Bores	Pin
		Fixed assemblages.		
A^1	B^1	Driven fit.	B^1	X^1
	C^1	Hammer fit.	C^1	
	S^1	Tight fit.	S^1	
	E^1	Accurate fit.	E^1	
		Moveable assemblages.		
	G^1	Sliding fit.	G^1	

Quality 2. ACCURATE. Black gauges.

Bore	Pins	Fit	Bores	Pin
		Fixed assemblages.		
A^2	P^2	Press fit.	P^2	X^2
	B^2	Driven fit.	B^2	
	C^2	Hammer fit.	C^2	
	S^2	Tight fit.	S^2	
	E^2	Accurate fit.	E^2	
		Moveable assemblages.		
	G^2	Sliding fit.	G^2	
	D^2	Tight turning fit.	D^2	
	T^2	Turning fit.	T^2	
	F^2	Easy turning fit.	F^2	
	L^2	Free turning fit.	L^2	

Quality 3. CAREFUL. Yellow gauges.

Bore	Pins	Fit	Bores	Pin
		Moveable assemblages.		
A^3	G^3	Sliding fit.	G^3	X^3
	T^3	Turning fit.	T^3	
	L^3	Free turning fit.	L^3	

Quality 4. ORDINARY. Green gauges.

Bore	Pins	Fit	Bores	Pin
		Moveable assemblages.		
A^4	G^4	Sliding fit.	G^4	X^4
	T^4	Turning fit.	T^4	
	F^4	Easy turning fit.	F^4	
	L^4	Free turning fit.	L^4	

TABLE II. — **Gauges for press fit bushes.**

Nominal diameter.		Bore (motion parts)		Bushes (Outside turning)		Grip.	
				G3 pr. finish			
above... millimetres	up to... millimetres	Quality « Careful » A3 (microns)		Maximum (microns)	Minimum (microns)	Minimum (microns)	Maximum (microns)
18	30	0	+ 45	+ 200	+ 155	110	200
30	50	0	+ 50	+ 200	+ 150	100	200
50	60	0	+ 60	+ 210	+ 150	90	210
60	70	0	+ 60	+ 220	+ 160	100	220
70	80	0	+ 60	+ 230	+ 170	110	230
80	90	0	+ 70	+ 240	+ 170	100	240
90	100	0	+ 70	+ 250	+ 180	110	250
100	110	0	+ 70	+ 260	+ 190	120	260
110	120	0	+ 70	+ 270	+ 200	130	270
120	180	0	+ 80	+ 280	+ 200	120	280

Hammer driven bolts (cylinder fastenings) are another case of the same sort. The finish « Accurate » A2 has been adopted for the hole, as it is easily obtained with good reaming tools ; for turning the body of the bolts, the finish G3 is used with the nominal diameter increased sligthly to get the necessary grip and this gives the fit G3 ch. (« chassé ») (G3 hammer driven) (table III).

Likewise, for the sliding bolts the boring finish « *Accurate* » A2 has been selected, and the « *Careful sliding* » G3 fit for the bolt bodies (table III).

TABLE III. — **Gauges for hammer and sliding fit bolts.**

Nominal diameter.		Bore.		Bolts.			
				Hammer fit.		Sliding fit.	
above... millimetres.	up to... millimetres.	« Accurate » quality A2 (microns).		Finish G3 ham. (microns).		Finish « Careful » sliding G3 (microns).	
10	18	0	+ 18	+ 20	+ 55	0	— 35
18	30	0	+ 22	+ 22	+ 67	0	— 45
30	50	0	+ 25	+ 25	+ 75	0	— 50
50	80	0	+ 30	—		0	— 60
80	120	0	+ 35	—		0	— 70

The limit gauges are used not only for measuring fork ends but also for various machined out openings ; for example, the width of piston and piston valve ring grooves and the corresponding rings have been standardised by steps of 1 mm. (0.039 inch) in width for the pistons and of 1/4 mm. (0.0098 inch) for the piston

valves, with tolerances of 50 and 0 microns on the grooves, and —50 and —100 microns for the rings, which gives a mean play of 0.1 mm. (0.0039 inch). Tapered plug gauges are also used for checking fits such as the piston rod in the cross head, and in the piston.

Diagrams showing the standard dimensions of bolts, studs, screws, and rivets have been issued for the whole stock; screw threads are checked against micrometers and thread gauges ; for checking turned and polished bolts (cylinder and horn sheet fastening bolts) a tolerance system similar to the Newall has been adopted.

Standardisation of tools. — Standard drawings have been prepared for all tools. The tools are made and sharpened in a special shop equipped for the purpose ; plate IX reproduces a sample drawing of this kind.

***

This standardisation and working to limits has had a radical influence on the cost and on the speed and quality of the work done. As a result, many spare parts are now mass-produced on special machine tools, and stocks of standard parts have been formed, from which all the repair shops and sheds on the system draw.

II. — The plant.

The shops taken as a whole consist of two blocks of buildings separated by a 100-ton surface traverser of the portal type, 20 m. (65 ft. 7 in.) long (photograph I).

Each of the two blocks (Plate X) consists of an old shop (A'B') against which a new hall (A and B) has been built.

In halls A and B, which are served by overhead travelling cranes, locomotives are erected and heavy boiler repairs are carried out. In the layout adopted, the pits are arranged across the shop.

a) The erecting shop (Plate X).

The erecting shop A is divided into two sections measuring 18.30 m.×112 m. (60 ft.×367 1/2 ft.) each, with one 70-ton overhead travelling crane for lifting the engines and two 5-ton ones for handling materials. These shops, at different fixed locations, deal with the stripping of engines (heavy and medium repairs), repairing and re-erecting of frames and re-erecting of the repaired boilers.

The pits are 12 m. (39 1/2 feet) long and are lighted electrically by lamps fitted in the sides.

b) Repair shop for dealing with locomotive parts.

Shop A' is divided into 8 bays 91 m. (298 1/2 feet) long. The first 5 are provided with 1-ton overhead floor-operated cranes; each of these cranes is used in connection with the repair of a definite group of parts (secondary belt for rods, axle boxes, pistons and valves, motion, brake and spring gear). The last two bays are used for repairs to fittings and pipe work. The wash house and clothes lockers and the locomotive and tender paint shop are on the north side. The Schenk type locomotive weighing machine has been installed in the paint shop.

c) Boiler shop.

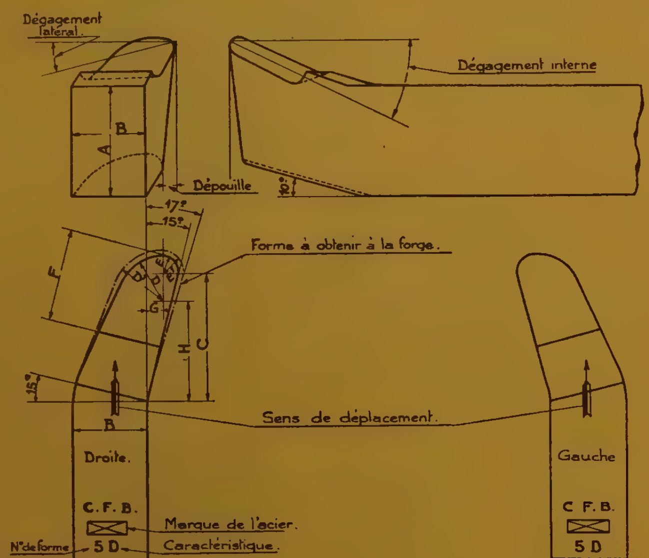
Boilers undergoing extensive repairs are dealt with in the main bay (21.5×104 m. = 70 1/2 ft.×341 ft.) of shop B. This shop has two overhead travelling cranes one above the other, of 40 tons and 5 tons capacity respectively.

In the secondary bay (15×104 m. =49 ft. 2 in.×341 ft.), which has a 5-ton overhead travelling crane, smoke tubes and superheaters are repaired. The boilers

MALINES MAIN REPAIR SHOPS.

Standardisation of tool dimensions and shapes.

Shape 5.
Side cutting tool. — Roughing tool.



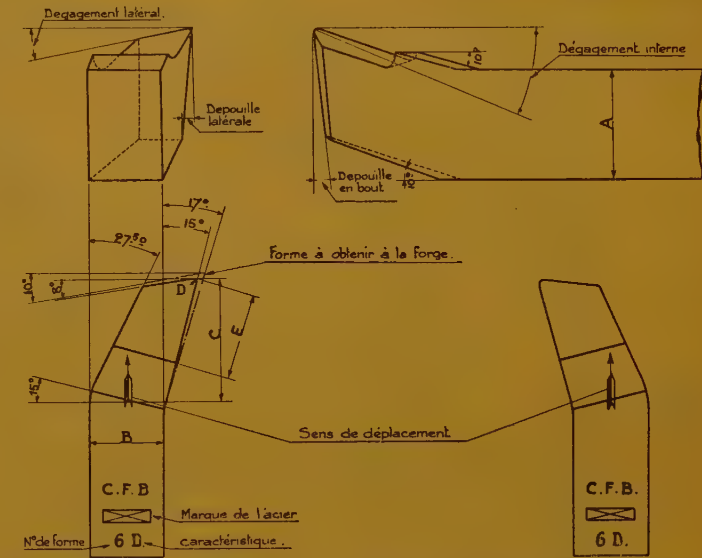
Dimensions of end according to section of tool.

A	B	C	D	D¹	E	E¹	F	G	H
20	15	26	9	9.6	3.5	4.1	20	3.5	20.5
25	15	26	9	9.6	3.5	4.1	20	3.5	20.5
30	20	35	12	12.8	5	5.8	25	4	28
35	25	44	16	17	6.5	7.5	30	5	34.5
40	25	44	16	17	6.5	7.5	30	5	34.5
40	30	52.5	20	21.3	8	9.3	35	6	40 5
45	30	52 5	20	21.3	8	9.3	35	6	40.5

Value of the angles according to the different materials to be machined.

Materials to be machined.	Mark.	Angles of backing off.	Angles of cutting.	Angles of clearance top.	Angles of clearance side.
Bronze	A	7°	90°	—	—
Hard steel, hard cast iron	B	7°	74°	14°	8°
Semi-hard steel, semi-mild steel, soft cast iron. . . .	C	7°	64°	22°	15.5°
Dead soft mild steel, red copper . . .	D	7°	55°	28.5°	24°

Shape 6.
Side cutting tool. — Finishing tool.



Dimensions of end according to section of tool.

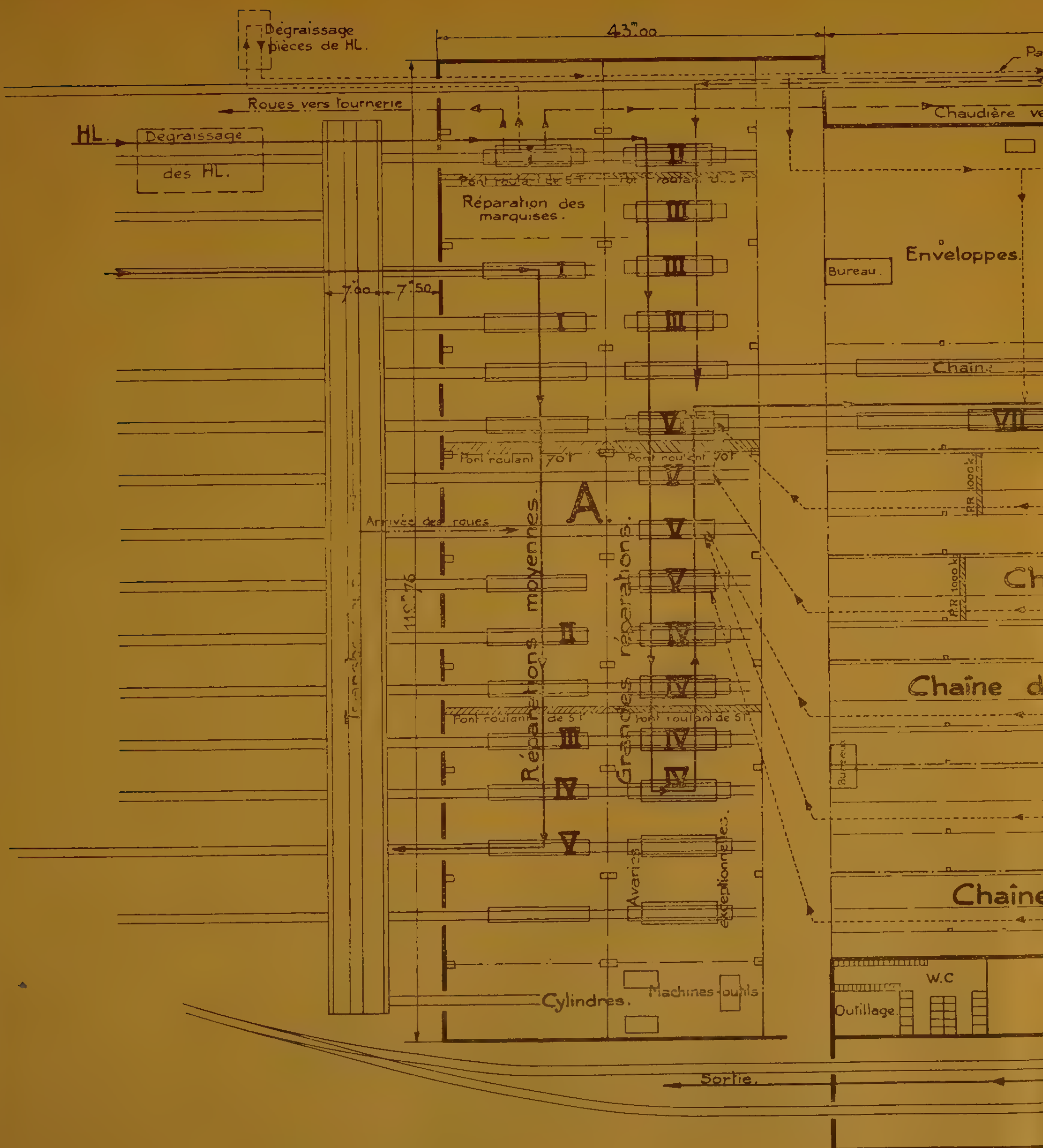
A	B	C	D	E
20	15	30	3/4	20
25	15	30	3/4	20
30	20	35	1	25
35	25	40	1 1/4	30
40	25	40	1 1/4	30
40	30	50	1 1/2	35
45	30	50	1 1/2	35

Values of the angles according to the materials to be machined.

Materials to be machined.	Mark.	Angles of backing off top.	Angles of backing off side.	Angles of cutting.	Angles of clearance top.	Angles of clearance side.
Bronze.	A	7°	4°	90°	—	—
Hard steel, hard cast iron	B	7°	4°	74°	14°	8°
Semi hard steel, semi-mild steel, soft cast iron	C	7°	4°	64°	22°	15.5°
Dead soft mild steel, red copper.	D	7°	4°	55°	30°	21.5°

Explanation of French terms in diagrams : Dégagement latéral = Side clearance. — Dégagement interne = Top clearance. — Dépouille = Backing off. — Forme à obtenir à la forge =

Diagram of the



A.

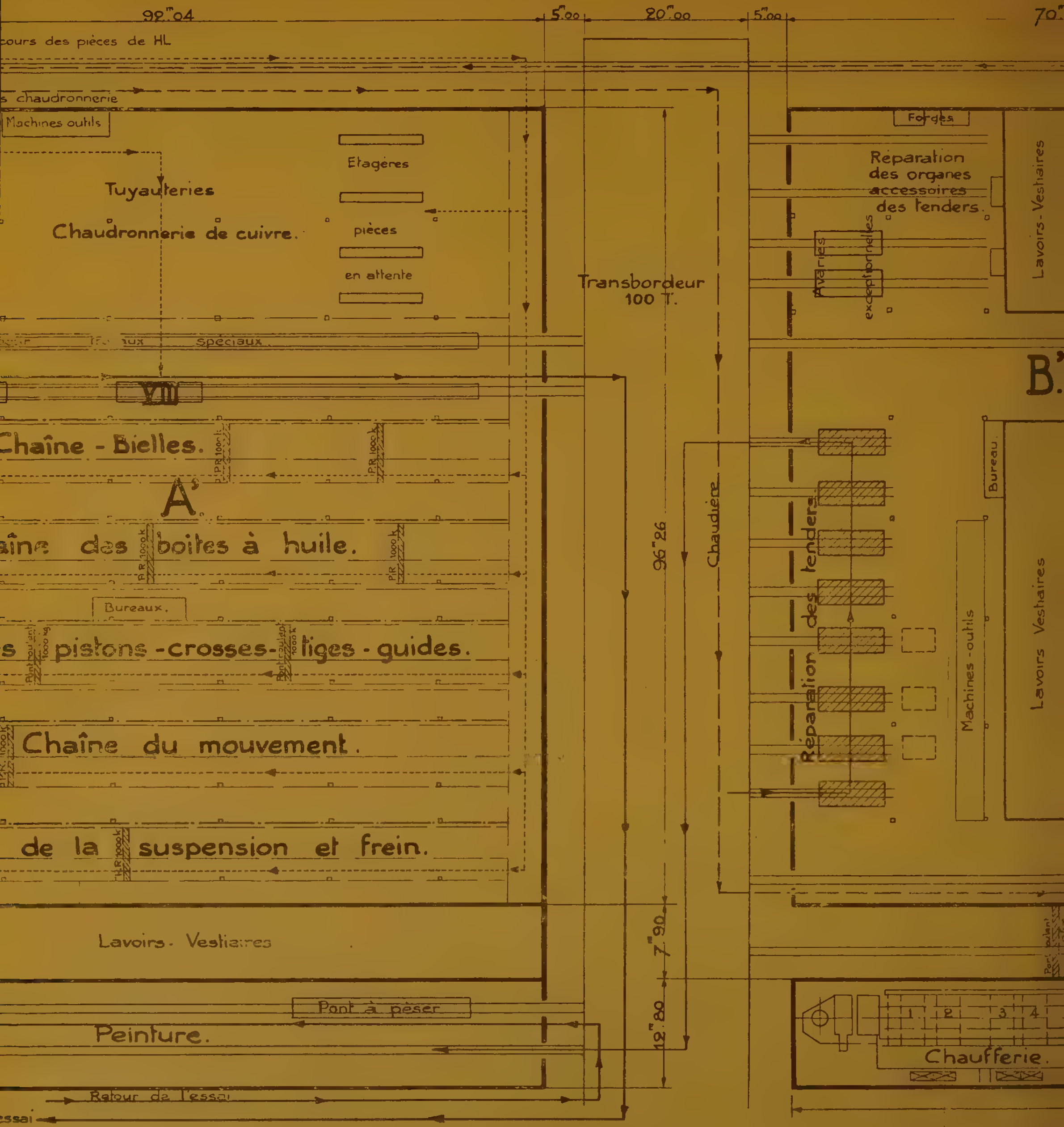
Dégraissage pièces de H. L. = Cleaning locomotive details.
Roues vers tournerie = Wheels to wheel shop.
H. L. = Locomotives.
Dégraissage des H. L. = Locomotive cleaning plant.
Transbordeur = Traverser.
Pont roulant de 5 t. = 5-ton overhead crane.

Réparation des marquises = Cab repairs.
Arrivée des roues = Wheels from wheel shop.
Réparations moyennes = Medium repairs.
Grandes réparations = General repairs.
Avaries exceptionnelles = Exceptional damage.
Cylindres = Cylinders.
Machines-outils = Machine tools.

A'.

Parcours des pièces
Path followed by
parts.
Chaudière vers la c
rie = Boiler to bo
Machines outils = Ma
Enveloppes = Laggin
Bureau = Office.
Tuyauteries = Pipe
Chaudronnerie de cui
persmiths.

e organisation of the work in the new shops at Malines. — Locomotive re



Explanations of French terms :

de H. L. =
locomotive

aaudronne-
ter shop.
hine tools.

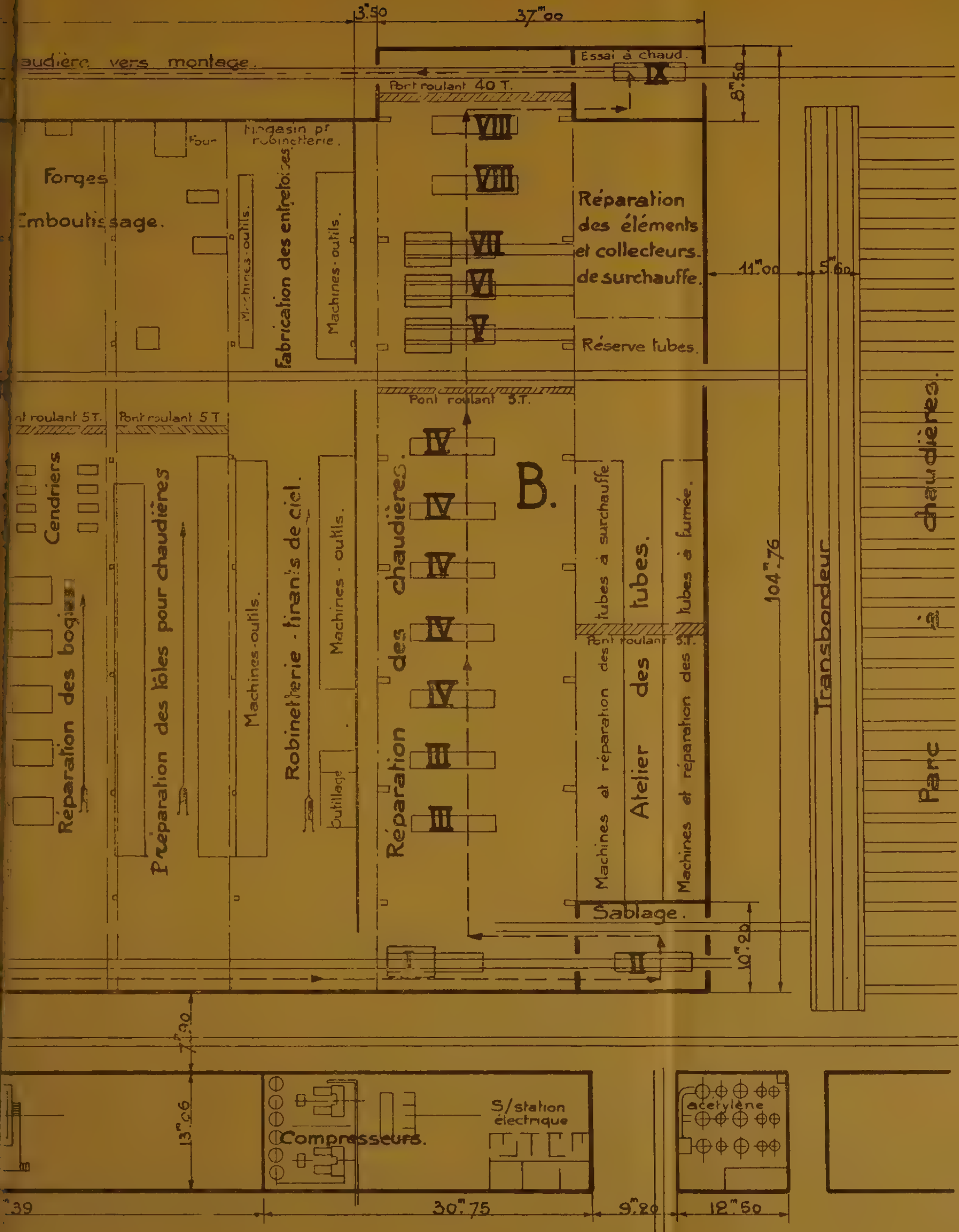
ork.
re = Cop-

Etagères pièces en attente = Racks for parts awaiting repair.
Chaîne pour travaux spéciaux = Belt for special jobs.
Chaîne-bielles = Rod belt.
Chaîne des boîtes à huile = Axle box belt.
P. R. = Overhead crane.
Bureaux = Offices.
Chaîne des pistons-crosses-tiges-guides = Piston, crosshead, piston rod and crosshead guide belt.

Chaîne du mouvement = Motion belt.
Chaîne de la suspension et frein = Spring gear and brake belt.
Lavoirs-vestiaires = Lavatories and clothes lockers.
Outillage = Tool room.
Peinture = Paint shop.
Pont à peser = Weighbridge.
Retour de l'essai = Back from trial run.
Essai = Trial.
Transbordeur 100 t. = 100-ton traverser.

B'.

Chaudière vers montage =
to erecting shop.
Forges = Smith fires.
Réparation des organes
soires des tenders = R
to tender details.
Lavoirs-vestiaires = Lava
and clothes lockers.
Forges. Emboutissage = S
Press shop.
Four = Furnace.
Magasin pour robinetter
Brass stores.
Fabrication des entretois
Stay shop.



Machines-outils = Machine tools.
Pont roulant = Travelling crane.
Réparation des tenders = Repairs to tenders.
Cendriers = Ashpans.
Réparation des bogies = Bogie repairs.
Préparation des tôles pour chaudières = Boiler plates, preparation of.
Robinetterie — tirants de ciel = Brass work, roof stays.
Chaufferie = Heating boilers.
Compresseurs = Compressors.
Station électrique = Electric sub-station.

B.

Essai à chaud = Hot test.
Réparations des éléments et collecteurs de surchauffe = Repairs to superheater elements and headers.
Réserve tubes = Tube stock.
Machines et réparation des tubes à surchauffe = Flue tubes repairs and machinery.
Machines et réparation des tubes à fumée = Smoke tube repairs and machinery.
Sablage = Sand blast.
Acétylène = Acetylene plant.
Parc à chaudières = Spare boilers.

Photo 1. — Locomotive traverser between the two groups of buildings in which the locomotives are repaired.

are steam-tested in a shed at the south end of the tube shop, and the sand blast plant for cleaning the boilers inside and outside is located at the north end of the same shop.

d) Manufacture of boiler parts.

All the equipment, machine tools and fittings, are grouped in three bays of shop B', nearest the boiler shop.

Two of these bays are served by a 5-ton overhead travelling crane, floor-controlled.

Heavy and medium tender repairs are carried out in the part of shop B' near the 100-ton traverser ; ample washing and cloak room accommodation has been provided.

e) Special installations.

Central heating. — A modern heating plant consisting of 5 multitubular boilers (Jiges) of 220 m² (2 368 sq. feet) heating surface and 12 kgr./cm² (170.7 lb. per sq. inch) pressure, produces the steam used for heating the buildings as well as for operating the steam hammers, locomotive cleaning plant, laundry, etc.

Each of the boilers produces 5 000 kgr. (11 000 lb.) of steam per hour (6 000 kgr. [13 200 lb.] when forced).

The shops are heated by Westinghouse system aerotherms.

Photo 2. — View of boiler shop.

Compressed air plant. Compressed air is supplied by two twin compressors direct driven by 250-H.P., 6 000-volt synchronised induction motors.

The capacity of each compressor is 30 m^3 (1 060 c. feet) of free air per minute.

Acetylene plant. — There are three low-pressure acetylene producers, each yielding 12 000 litres (424 c. feet) of gas an hour.

Oxygen is purchased in tank wagons at a pressure of 150 kgr./cm^2 (2 133 lb. per sq. inch). Each wagon carries 5 tubes of 920 litres (35 c. feet) water capacity and can consequently supply about 700 m^3 (24 720 c. feet) of free oxygen.

Pipe lines. — Steam, compressed air, oxygen, and acetylene are distributed through the whole of the new shops by a system of all-welded pipe lines which are tapped at many points.

Each line has a distinct colour.

Electric power is supplied as alternating current at 6 300 volts, by private power stations. This current is transformed in substations into either alternating current at 220 or 440 volts or direct current at 220 volts.

Works transport. — The works transport is divided into three groups:

a) Between the stores and departments outside to main shops : by wagon or motor lorry ;

b) Stores to each shop, and shop to shop. This covers materials for the shops, and from one shop to another, finished parts to stores, and the removal or collection of useful scrap.

This work is done by trailers hauled by motor tractors. Many wide concrete paths have been laid down throughout the works, the total length being 2 km. (1.2 miles). A regular transport service has been organised, covering several circuits over which the trucks and tractors run at fixed times. The trucks are unloaded in each shop at fixed points at certain times which are carefully checked.

c) *Inside shops.*

Accumulator trucks, small service cranes, or the travelling cranes are used for this work.

Motion and brake parts, and plates are stacked on stools 1 m.×1.20 m.×35 cm. high (3 ft. 3 3/8 in.×3 ft. 11 1/4 in. ×1 ft. 1 3/4 in. high), which are lifted by the trucks and carted away.

The small parts are sorted into containers.

The paths in the shops are painted white so that the trucks can circulate through the shops freely. These paths must be kept clear of obstruction so that the trucks can be operated at speed without being obstructed in any way.

III. — Organisation of the repair belts.

The repairs, whether to the frame, boiler, or parts of the locomotive, are done on the belt system.

As we have already said, the belts in question move forward at intervals, each movement being at regular intervals and bringing the vehicle or parts to the stands specially equipped for the particular job to be done.

There are four main belts : frames of locomotives undergoing heavy repairs ; heavy boiler repairs ; medium locomotive repairs ; heavy and medium tender repairs; and secondary belts which feed the repaired parts to the main belts.

Each secondary belt (rods, boxes, etc.) forms a separate unit with its own electric welding plant, machine tools, and the fitters for *completely* repairing the different details. These elements are arranged in line, in chronological order, so that the work goes forward regularly without any cross movements. No mass production work is done at these belts, all manufacturing being concentrated in a shop equipped with high productive capacity machinery.

As shown on plate X, the secondary belts are arranged to feed the main belts directly.

This layout reduces handling considerably. The general supervision of the shop is easily carried out. Any hitch is localised at once and is corrected on the spot so as to prevent any reflex action on the belts.

A. — Main belts.

a) *Heavy repairs.* — The path followed by a locomotive and its frame, when being given a heavy repair, is shown by a full line on plate X.

Before the locomotive is put into the erecting shop, it is put on the cleaning road where it is cleaned by jets of hot water mixed with soda and sand. It then goes to stand No. 1, where it is stripped of its piping, fittings, lagging, smoke box parts, boiler, wheels.

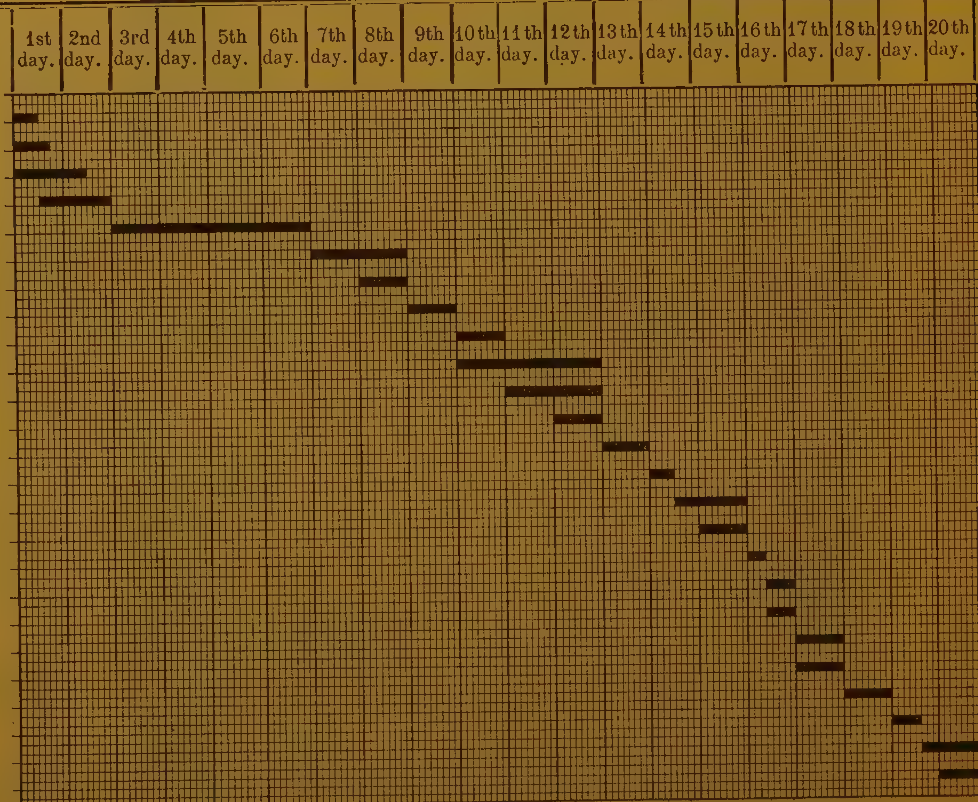
The whole of these operations takes

Malines Main Repairs Shops.

Standard schedule.

LOCOMOTIVES.
Heavy repairs.

No.	OPERATIONS.
1	Lifting boiler from frame
2	Removing wheels
3	Stripping down motion
4	General clean down
5	Frame repairs
6	Fitting steam chest liners
7	Boring out cylinders
8	Boring out steam chest liners
9	Painting frame
10	Fitting slide bars
11	Repairing foot plate
12	Erecting spring gear
13	Fitting reversing gear lever
14	Wheeling
15	Putting up brake, pistons, motion
16	Putting up rods
17	Dropping boiler onto frame
18	Putting up cab
19	Fitting pumps
20	Lagging
21	Fitting blast pipe
22	Putting up pipe work
23	Trial run
24	Finish painting
25	Touch up



four working hours during which one of the 5-ton travelling cranes is set aside for the use of the stripping gang.

The boiler is turned upside down, dropped onto a special truck and sent to the boiler shop by means of the main traverser, the path followed being shown by dotted lines in plate X. The frame is put on small trucks and returned to the cleaning road where it is jet-cleaned a second time and then is taken to stand II where the stripping down is completed.

The details are cleaned in a soda bath and then distributed to the different secondary belts. The frame is scraped and then carefully examined. These operations correspond to the *first two days* of the schedule (plate XI).

3rd day : The frame is placed by the overhead travelling crane on one of the stands marked III where it remains four days during which all necessary repairs are given it (straightening frames, replacing cylinders, hornsheets, dray boxes, welding, etc.).

7th day : The frame is moved to one of stands IV (7th to 12th day) where it is levelled to see it is square. After the frame has been checked over and the axle box guides have been trued up by portable grinding machines, the measurements for finishing the axle boxes are read off.

The cylinders are bored out and the piston valve sleeves are put in, bored out and ground up, and measured off. The slide bars are also put up.

13th day : The frame is moved to one of stands V (13th to 15th day) and all the motion, spring gear and brake parts are erected.

15th day : The engine is wheeled.

16th day : The repaired boiler is lowered onto the frame (stand VI), the cab is replaced, and the boiler lagging is put up; the feed water equipment is also re-erected.

17th day : All mountings are replaced (stand VII).

18th day : The piping is refitted.

19th day : The engine goes out on trial.

20th day : Any adjustments required are made, and the painting is finished off.

These different stages in the repair are shown graphically on the standard schedule, plate XI.

This schedule appears to be very long as regards frame repairs ; it is based on the time needed to repair the boiler. The principle has been laid down that boilers are only to be taken from the spare stock or the repairs done by working double shifts in quite exceptional circumstances. The standard boiler repair schedule has been based on the time required for doing the heaviest repairs, such as replacing a firebox and at the same time renewing part of the wrapper, barrel and smoke box plates.

b) *Boiler heavy repairs* (plate XII).

At midday on the first day of the general schedule, the boiler is taken to the boiler shop, the route taken being marked on plate X.

The firebox is then inspected. The boiler is then put under a gantry (stand I) with electric drills for drilling out the stays.

The copper plates which have to be removed are sectioned up by drilling rows of holes.

While the stays are being drilled out, the tubes are removed. The whole of this work is finished by *midday of the second day*.

Malines Main Repair Shops.

Standard schedule.

BOILERS.
Heavy repairs.

No.	OPERATIONS.		1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	11th day.	12th day.	13th day.	14th day.	15th day.	16th day.
1	Inspection																	
2	Drilling stays. Removing tubes																	
3	Cleaning by sand blast																	
4	Stripping																	
5	Preparing for marking off																	
6	Electric building up and welding																	
7	Replacing all plates																	
8	Bottom firebox casing																	
9	Tube plate																	
10	Riveting foundation ring																	
11	Riveting barrel																	
12	Screwing stay holes																	
13	Staying																	
14	Knocking down stay heads																	
15	Replacing tubes and mountings																	
16	Cold and hot test																	
17	Adjustments (if required)																	
18	Transport to erecting shop																	
19	Lowering onto frame																	

The boiler is then moved to stand II (sand blast). The inside of the barrel is sand-blasted automatically by a jet nozzle which is given a helicoidal motion. The outside is sand-blasted by a hand operated jet nozzle.

The barrel is minutely inspected immediately after being sand-blasted.

3rd day : The boiler is moved to stand III by the overhead crane and is stripped down. The rivets, bars, and stays are cut out with pneumatic hammers; the plates are cut out and taken away by the 5-ton crane.

The new firebox tube plate or back plate is offered up on the *afternoon of the fourth day.*

To complete stripping, the parts thus opened up are cleaned and all chippings, stay ends, bolts, and rivets removed.

5th day : Any electric welding, building up corroded parts, welding up flanges or closing up oversize plug holes is done this day.

6th, 7th, 8th and 9th days : Re-assembling, riveting, caulking all plates (stand IV).

10th day : Tapping stay holes (stand V).

11th day : Driving stays (stand VI).

12th day : Heading stays (stand VII).

Each of the last three stands has a gantry with the necessary equipment ; the first gantry has 6 electric drills for tapping, suspended from the structure; the second has 6 electric stay drivers; the third has pneumatic hammers for closing down the two stay ends simultaneously.

13th day : Mounting (tubing, putting on fittings, etc., stand VIII).

14th day : Cold and hot tests (stand IX).

15th day : This is spare so that any delay in completing the boiler work will not interfere with the movement of the main frame belt. During this day, any defects revealed by the tests are made good. On the evening of this day, the boiler is taken to the erecting shop for dropping onto its frame on the 16th day (morning) (standard schedule, plate XI).

This schedule is used for the heaviest repairs. In a few exceptional cases only (such as replacing a throat sheet) is it necessary to work double shifts at the erecting stands.

The time for a complete repair is consequently $8 \times 13.5 = 108$ hours.

General repairs to boilers are usually extensive; the tube plate and firebox half sides nearly always have to be renewed, while the lower half of the barrel plates frequently require to be changed; on the other hand the firebox back plate, the smoke box tube plate and the firebox casing have to be renewed less frequently.

Tube plates cracked or otherwise seriously defective are always replaced as a whole; repair by autogenous welding is only authorised in the case of medium repairs.

The same rule applies to the back plate; the firebox opening, and the flanges are sometimes patched and welded.

The lower parts of the firebox copper plates are renewed by welding in new plates, by oxy-acetylene welding, a gang of four welders relieving each other in pairs doing the work.

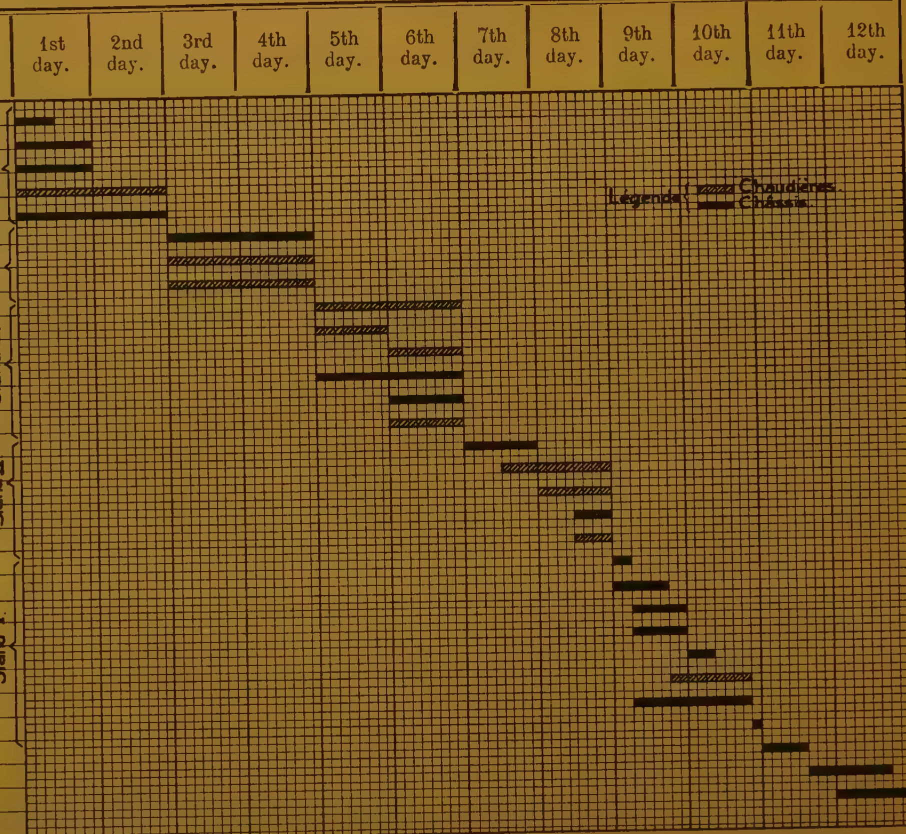
The firebox outer half sides are usually renewed when the stay holes become too large ; if the number of holes to be made good is not too great, the holes are bushed. As a rule, however the half side is replaced, the new plate being welded in electrically.

Malines Main Repair Shops

Standard schedule.

LOCOMOTIVES.
Medium repairs.

No.	OPERATIONS.	
1	Lifting off wheels	Stand I.
2	Stripping frame	
3	Removing lagging	
4	Lifting boiler out of frame	
5	General clean down	
6	Frame repairs	Stand II.
7	Renewing boiler studs	
8	Drilling and removing stays	
9	Riveting and caulking boiler	Stand III.
10	Screwing stay bushes	
11	Putting in stays	
12	Repairing cylinders	
13	Repairing foot plate	
14	Replace boiler mountings	
15	Putting cab back	Stand IV.
16	Retubing	
17	Putting up grate and ashpan	
18	Putting up spring gear	
19	Fitting lagging	
20	Rewheeling	Stand V.
21	Erecting motion	
22	Fitting draw and buffer gear	
23	Putting up rods	
24	Fitting up brake	
25	Fitting up smoke box	
26	Refitting pipe work	
27	Engine leaves shop	
28	Trial run	
29	Finish painting	
30	Adjustments after trial	



Note : Chaudières = Boilers. — Châssis = Frames.

As regards barrel repairs, electric welding is not allowed; the only welding allowed, and to a very limited extent, is building up corrosion pit marks.

Barrel plates or half plates are very frequently renewed; patching or plating the barrel is not allowed.

If a new inner firebox is to be fitted, the new firebox is got ready beforehand; it is offered up for marking off and then finished off and fitted to the barrel; this causes practically no alteration to the schedule.

c) *Medium locomotive repairs.*

There is little difference between a heavy and a medium repair, as regards the frame; in the latter case, slightly greater latitude is allowed when squaring up. All motion details, spring gear and brake gear receive the same attention in both classes of repair.

The chief difference lies in the boiler repairs: only essential boiler repairs are carried out; the tubes are usually renewed; badly worn stays are replaced and the remainder hammered up. It is quite usual for 100 to 300 stays to be renewed.

When there are unimportant cracks in the tube plates, the tube plate is often repaired by welding in patches by oxy-acetylene.

The fittings and feed water appliances are thoroughly repaired.

When undergoing medium repairs, the locomotive follows a schedule of five phases, each of two days: the eleventh day is set aside for the trial run and the 12th for final attention and finish painting.

The standard schedule (plate XIII) shows the main stages of a medium repair.

d) *Tender repairs.*

The tenders are repaired quite separately from the locomotives.

The tender shop consists of the repair stands, welding stand, smithy, machine tools, and fitters benches.

There are also two classes of repair (heavy and medium), the main difference being the extent of the repairs to the water tank.

There is only one belt, however, and the periods are the same in both cases.

The tenders pass in turn five stands. The total time for the repairs is 7 days (plate XIV).

As the old shop was not suitable for an overhead lifting crane, the tenders are moved by means of the 100-ton traverser.

For this purpose, when the tender is lifted off its wheels, it is lowered onto shop trucks specially designed so as not to be in the way when repairing the water tanks.

1st day: All parts of the frame are stripped down and the wheels removed. Stand I is fitted with electrically-driven lifting jacks for this purpose.

2nd day: (stand II). Outside and inside cleaning.

3rd to 5th days: The water tanks and coal bunkers are repaired, badly worn plates and corroded rivets are renewed (stand III). The frame is repaired, squared up, welded when necessary, frame plates straightened, etc.

6th day (stand IV): The brake and steam heating pipes are refitted and the draw gear put up.

7th day (stand V): The tender is rewheeled and all details re-erected.

The tender is then repainted in the locomotive paint shop.

Malines Main Repair Shops. Standard schedule.

TENDERS.
Heavy and medium repairs.

N°.	OPERATIONS.	
1	Removing wheels	Stand I.
2	Taking down brake	
3	Taking down draw gear	
4	Cleaning out tanks	Stand II.
5	Cleaning out bunkers	
6	Cleaning frame	
7	Painting frame	Stand III.
8	Welding frame	
9	Squaring up	
10	Repairing tool chests	Stand III.
11	Strengthening tanks	
12	Removing defective plates	
13	Replacing plates	
14	Riveting	
15	Fitting draw and buffer gear	Stand IV.
16	Fitting brake and spring gear	
17	Fitting pipe work	
18	Fitting front buffer beam	Stand V.
19	Rewheeling	

1st day. 2nd day. 3rd day. 4th day. 5th day. 6th day. 7th day.

B. — Secondary belts.

Detail parts are repaired on five independent secondary belts:

a) connecting and coupling rods;

b) axle boxes;

c) pistons and piston valves;

d) valve gear;

e) brake, spring gear and draw gear parts.

Each secondary belt is in a 91-m. (298 1/2 ft.) long bay, through which the parts undergoing repair move continuously. All parts whether from a medium or a heavy repair follow the same path and undergo the same repairs in the same times.

The repair times are the shortest possible: they are fixed to fit in with the schedules for medium repairs and so are much shorter than necessary for heavy repairs. Parts for locomotives under heavy repairs have therefore to be kept on hand either before or after being repaired.

The first four belts have a main section which covers the parts to be repaired, and a secondary section which covers the stands where the fittings are got ready for repairs.

The two sections are separated by a gangway.

In the case of the brake belt, there is a main section only.

The machine tools are located near the secondary sections in such a way that the parts can be handled easily.

The work is organised at all five belts on the same lines as at the main belts; the secondary belts have stands specially set aside for certain definite tasks; the parts progress forward at regular intervals. The distribution of the work and its progress is regulated by the planning office (photograph 3).

The rod belt is represented in diagram form on plate XV; it is composed of one preparation phase and five repair phases, each of one day.

The preparation phase mainly consists of the *inspection*. The rod is levelled up on a face plate and its length, and if out of shape the amount, and the wear of the ends, are measured with precision instruments. When the dimensions measured exceed the limits of wear and tolerances allowed, the inspector decides the work to be done and fills in the inspection sheet. The differences are sometimes so great that the rod has to be sent to the smithy, after which the rod is measured up again.

Some of the rods have to be built up by electric welding and are sent to the welding stand for this purpose.

When such preliminary work has been done, the repairs properly speaking are taken in hand at stand I (plate XV), by facing up the side faces and boring out the ends.

As soon as this work is finished, the dimensions are entered on the prescribed form (stand 2) which in turn is used for getting the brasses ready (plate XVII). The knuckle joints are also bored out at this stand.

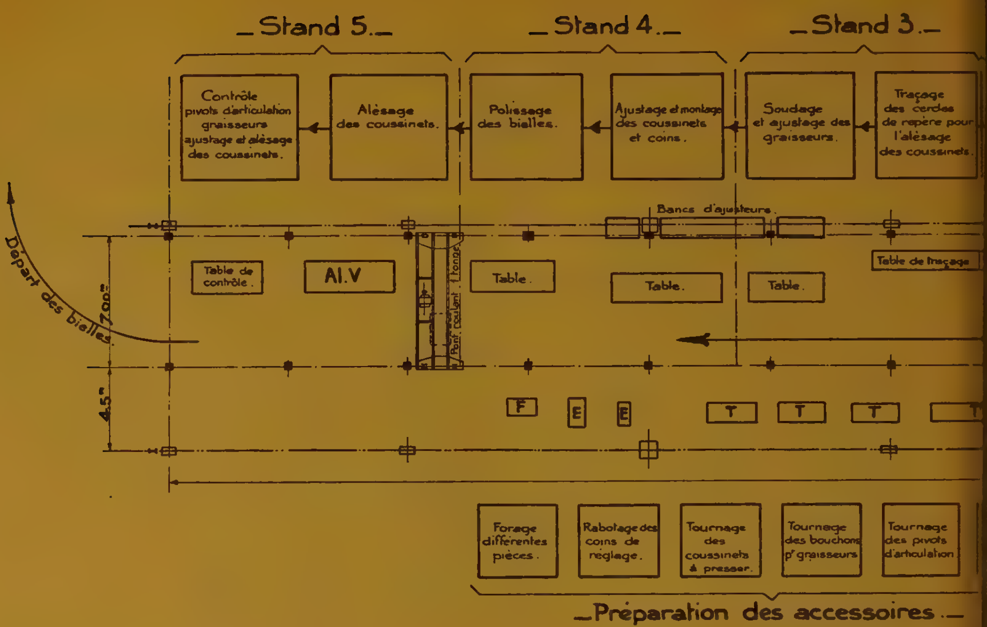
At stand 3 (3rd day), the coupling rods are assembled on a special table and circles are scribed on the side faces of the ends to locate the centres to which they are to be bored out. All centres are set to the dimensions on the drawings.

The lubricators are also repaired at stand 3.

At stand 4 (4th day), the big and little end brasses are fitted. The rods are polished by portable grinders this day.

The fully assembled rods are sent on the 5th day to stand 5 to have the brasses bored out (on a duplex vertical boring

Rod belt. — M



Explanations of French te

Stand 5 : Contrôle... des coussincts = Inspection of knuckle pins, lubricators; fitting and boring brasses. — Alésage des coussinets = Boring out brasses.

Stand 4 : Polissage des bielles = Polishing rods. — Ajustage... et coins = Setting and fitting brasses and wedges.

Stand 3 : Soudage... graisseurs = Welding and fitting lubricators. — Traçage... des coussinets = Scribing locating circle for boring brasses.

Stand 2 : Alésage des articulations = Boring out knuckle joints. — Contrôle... des cages = Checking the grinding and milling of rod ends.

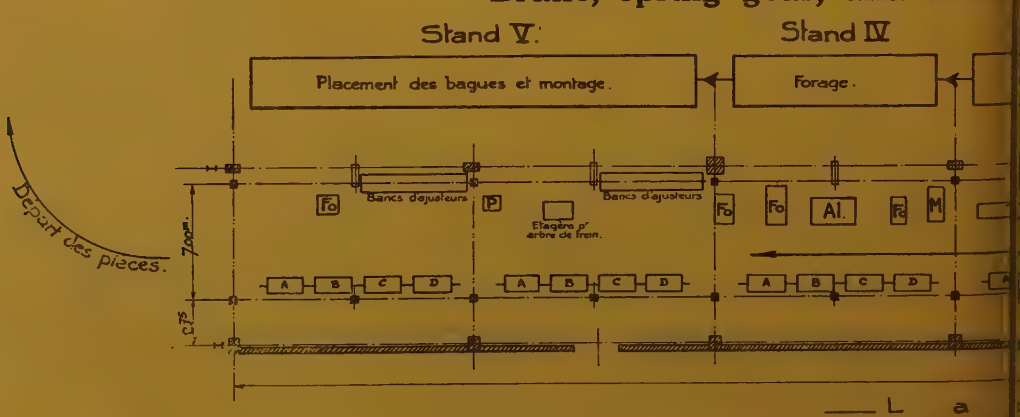
Stand 1 : Taraudage... de réglage = Tapping covers and bringing holes for wedges to standard. — Fraisage des cages = Milling ou rod ends. — Rectification... des cages = Grind ing sides of rod ends.

Preparation stand : Soudure = Welding. — Con trôle après forgeage = Inspection after smith work. — Visite = Examination.

Middle.

Bancs d'ajusteurs = Fitters benches.
Départ des bielles = Rods—out.
Table de contrôle = Inspection table.
Pont roulant 1 tonne = 1-ton travelling crane.
Table de traçage = Marking-off table.

Brake, spring gear, and draw



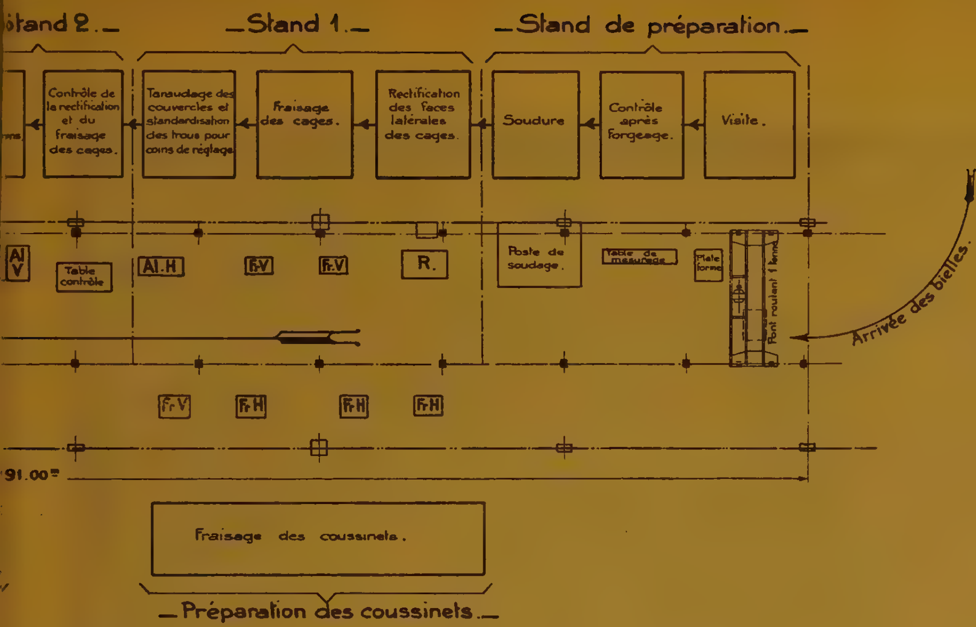
Explanations of French te

Placement... montage = Fitting bushes and assembling. — Forage = Drilling. — Tournage = Turning. — Fraisage et traçage = Marking off and milling. — Soudage = Welding. —

Visite des pièces = Examining parts. — Dépar des pièces = Parts—out. — Fo = Drill. - Bancs d'ajusteurs = Fitters benches. — P - Press. — Etagère pour arbre de frein = Rac

Main Workshops.

PLATE XV.



abbreviations (Plate XV) :

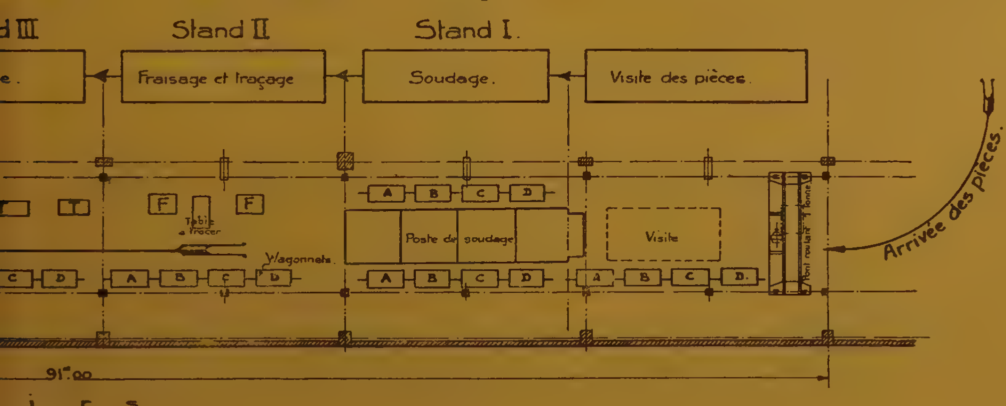
= Press.
I. V. = Vertical boring mill.
I. H. = Horizontal boring mill.
r. V. = Vertical milling machine.
= Grinder.

oste de soudage = Welding stand.
able de mesurage = Measuring-up table.
lateforme = Platform.
rrivée des bielles = Rods—in.
= Drill.
= Shaping machine.
= Lathe.
r. H. = Horizontal milling machine.

Bottom.
Préparation des accessoires = Preparation work on details.
Forage différentes pièces = Drilling different parts.
Rabotage... de réglage = Planing wedges.
Tournage... à presser = Turning pressed-in bushes.
Tournage... graisseurs = Turning lubricator plugs.
Tournage... d'articulation = Turning knuckle joint pins.
Filetage... étriers = Screwing stirrup ends.
Préparation des coussinets = Preparatory work on brasses.
Fraisage des coussinets = Milling brasses.

r belt. — Malines Main Workshops.

PLATE XVI.



bbreviations (Plate XVI) :

for brake shaft. — Al. = Boring mill. — M = Slotting machine. — T = Lathe. — F = Milling machine. — Table à tracer = Marking-off table. — Wagonnets = Trucks. — Poste de soudage = Welding stand. — Visite = Examination. — Arrivée des pièces = Parts—in. — Pont roulant 1 tonne = 1-ton travelling crane. — Lavoirs = Lavatories.

Photo 3. — Work distribution office (planning office).

mill). The holes are bored to the centres determined from the circles scribed on the faces of the rod ends. The dimensions are given on a card filled in to suit the dimensions of the crank pins.

The work done is finally checked for quality : knuckle pins, fitting of brasses, boring dimensions, condition of lubricators.

The *other detail parts are prepared* in the left bay of the belt.

The brasses, with their white metal linings already fitted, are milled to the dimensions of the rod ends.

The knuckle pins, oil plugs, wedges, and wedge bolts are machined on special machine tools to the dimensions given on the cards.

The *work is checked* systematically at definite times and places.

The inspectors have fixed time allowances for checking the work, so that their work fits in with the belt like the ordinary repair jobs.

By grouping the inspection operations, it has become possible to use specially accurate measuring instruments. Tolerances have been fixed for each dimension so that there can be no argument between the inspector and the man doing the work. These tolerances are shown on cards hung up at the inspection benches.

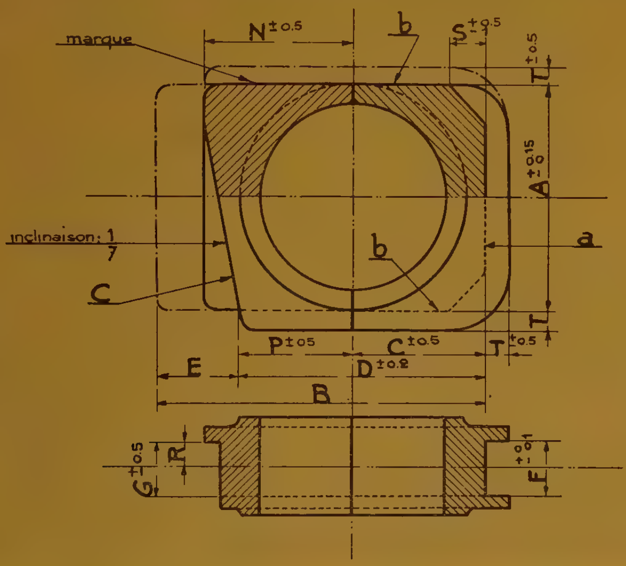
The application of the belt method is

MALINES MAIN SHOPS.

Measurement sheet.
Milling brasses.

Rod belt.

Locomotive type 81.
No. ... .



Brass.	No.	A	B	C	P	D = P + C	F	R	G = R + $\frac{F}{2}$	N	T	S	E = B − D
Connecting rod.	1				114.5			43		140	20	35	
	2				114 5			43		140	20	35	
Coupling rod.	1				71.5			26		87	20	25	
	2				114.5			31		140	20	35	
	3				71.5			31		87	20	25	
	4				71.5			26		87	20	25	
	5				71.5			26		87	20	25	
	6				71.5			31		87	20	25	
	7				114.5			31		140	20	35	
	8				71.5			26		87	20	25	

Note : Marque = Mark. — Inclinaison = Slope.

Photo 4. — Rod belt.

even more clearly seen in the case of the brake belt (plate XVI).

The different parts of the brake, draw, and spring gear are distributed between four trucks which form a small train. Each day this train passes from one stand to the next one until the repairs are completed.

The belt serves five stands, each of one day, like the rod belts.

* * *

The development of these belts represents the fruit of much research work and gradual improvements. Starting with a shop in which the locomotives were given over to gangs who repaired them with greater or less success, according to the ability of the charge hand, the repair shop has become a properly organised unit in which all parts fit together properly according to the plans of the main progress office.

When considering the secondary belts, the preparatory work was made quite separate from the manufacturing side. A beginning in the way of concentration was then made by bringing together all work on one group of parts. The operations were then gone into and classified in chronological order and sections were set up in which the parts were made to move forward in one direction.

Improvements in tools, and reductions in the times allowed, involved constant revision of the estimates, rates, and standard schedules.

The inspection of the work done was then organised ; the tolerances were closely gone into, and the manufacture of special measuring devices was pushed forward.

Finally, by introducing stands in sequence, each for the same period, and by moving the parts at fixed times always in the same direction, the sections were converted into real repair belts.

* * *

Carriage repairs.

The main shops at Malines are responsible for the heavy repairs to the whole of the passenger rolling stock.

Most of the stock is 6-wheeled, with wood body framing covered with steel plates or teak panelled. The number of bogie vehicles with wood body framing is relatively small. The all-steel bogie vehicles are quite new.

The Malines shops are therefore principally occupied with repairs to 6-wheeled stock.

The carriage shops, like the locomotive section, have been completely remodeled, both as regards the organisation itself and from the technical point of view.

The same principles have been followed ; all work is prepared by the main production office, the distribution and carrying out and control of the work then falling to the planning offices.

The work is organised on a belt which has a number of stands at which the repair work is done in equal periods. The detail parts are repaired on secondary belts arranged to avoid all unnecessary handling.

New parts are issued from stores, which are stocked either by purchase or from the manufacturing section where the parts are mass-produced.

The shop is divided into two main sections (plate XVIII) :

A) *a building, 241×71 m. (790 1/2 ft. ×233 ft.).*

All body and frame repairs are done in this shop and all fittings are put up.

This shop includes the secondary belts for getting ready the different detail parts.

It contains :

a) the brake, heating, and lighting repairs;

b) locks, tread plates, and hinges repairs;

c) saw mill with marking off benches, for machining frame timbers;

d) plate section;

e) secondary belt for making and repairing doors;

f) section for small cabinet work;

g) polishing benches;

h) section for repairs to the electrical equipment of the coaches (shown on plate XVIII under the name « Stone »).

i) wheel shop.

B) *a building, 241×45 m. (790 1/2 ft. ×148 ft.)* used as the carriage paint shop.

The finish coats of paint are applied in a separate and specially heated section of this shop, in which there is also the secondary belt for making seats and backs and the nickel plating shop.

Repair belt.

While the locomotive stock of the Belgian National Railways includes a great

many different designs, the number of types of passenger vehicles is still much greater. Many of the vehicles have undergone extensive alterations and their ages vary from 10 to 40 years.

The result is that the work to be done varies considerably both as to kind and to extent. There is also great difficulty in supplying the spare parts required.

In spite of this, the repairs have been organised on a belt system with a fixed number of phases of equal length.

The belt has 26 stands, each of 4 hours, and 20 stands for painting, each of 4 hours also.

The general arrangement of the belt is shown diagramatically in plate XVIII.

The vehicles are brought into the repair shop at A. The number one line which runs right through the shop has 11 stands. On leaving stand No. 11, the vehicle is moved by the traverser on to one of stands 12, 13 or 14. The vehicle stays here for three phases and then goes to stand 15 on a second longitudinal line which has 12 stands.

The completely repaired vehicle leaves at B.

The traverser then moves the vehicle to the painting belt.

The chief work done at each stand is :

Stand 1. Inspection. Cut out rivets and bolts. Remove springs.

Stand 2. Strip inside and outside fittings.

Taking down brake, heating and lighting equipment. Undo body bolts.

Stand 3. The body is lifted by jacks and the frame moved to the special frame section A' where it is fully repaired (welding, riveting, straightening sole bars, etc.).

Stand 4. Outside panelling (wood or metal) removed. Body frame examined.

Stand 5. Any defective parts of body framing removed.

Stand 6. Inspection for preparation of body framing parts.

Stands 7, 8 and 9. Phases during which the body is moved forward, but no work done to it ; waiting repaired parts.

Stands 10 and 11. Refitting brake and heating, and draw gear.

Stands 12 and 13. Repairing body framing.

Stand 14. Inspection of body framing.

Stand 15. Re-erecting floor and roof.

Stand 16. Repanelling outside.

Stand 17. Re-erection of intermediate partitions.

Stand 18. Inspection of work done at stands 15, 16, 17.

Stand 19. Putting in seats.

Stand 20. Fitting doors.

Stand 21. Moulding up.

Stand 22. Inspection of work done at stands *19, 20, 21.*

Stands 23 and 24. Completion of work and any alterations found necessary. Putting back fittings in the 1st and 2nd-class coaches.

Stand 25. Lifting : The carriage has been moved on its own wheels so far; when it is lifted, the wheels are replaced by a new set got ready in advance. The repaired springs are fitted and the heating and brake tests carried out.

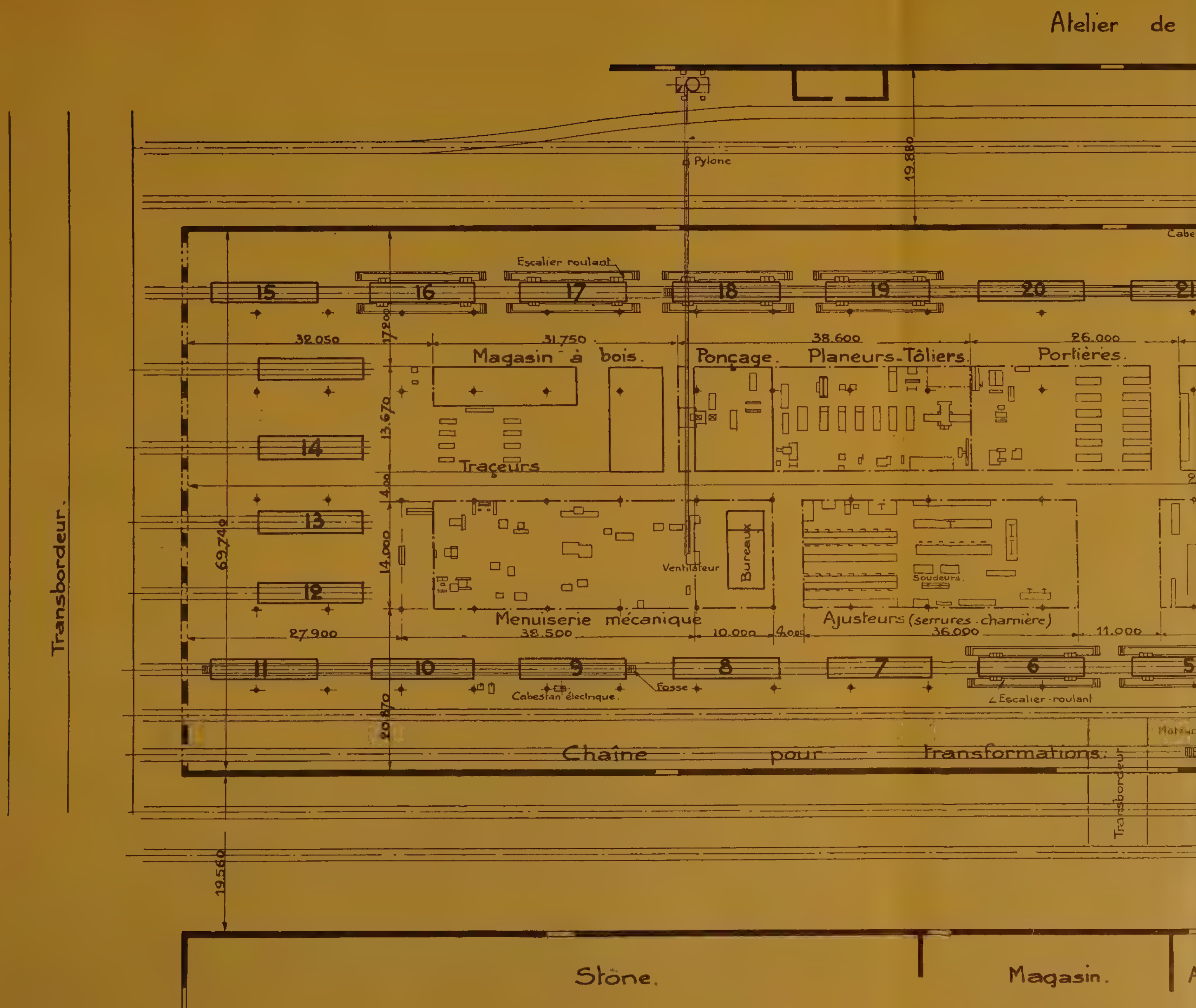
Stand 26. The foot boards are refitted and the vehicle generally inspected.

* * *

Very great difficulties were met and overcome before this belt was got into proper working order.

The number of men needed per stand

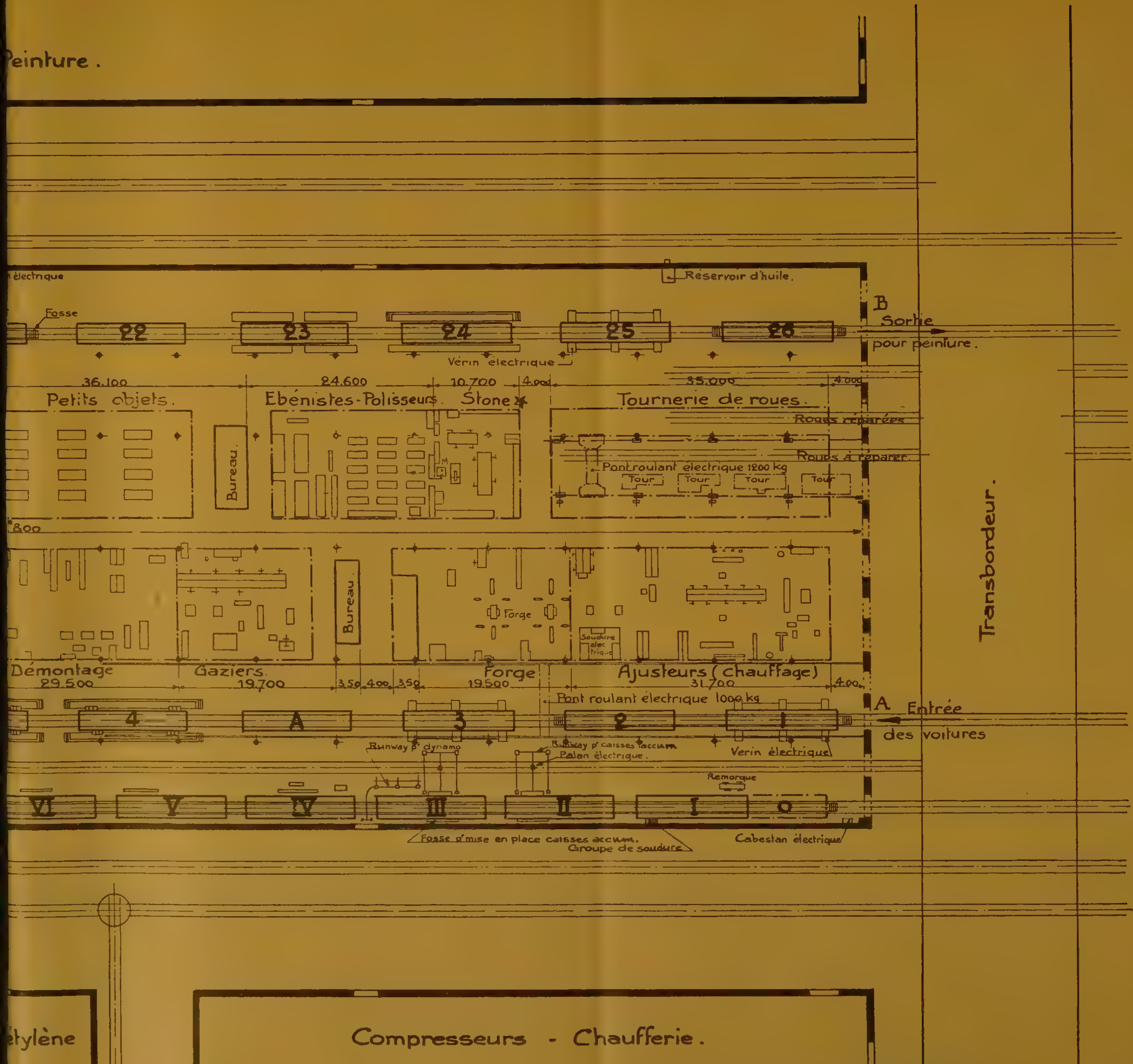
Diagram of carriage repair belt



Upper half :
Atelier de peinture = Paint shop.
Pylone = Pylon.
Cabestan électrique = Electric capstan.
Réservoir d'huile = Oil tank.
Escalier roulant = Moving staircase.
Fosse = Pit.
Sortie pour peinture = Out-for paint shop.
Vérin électrique = Electric jack.
Magasin à bois = Wood stores.
Traceurs = Markers off.
Ponçage = Rubbing down.

Planeurs = Planishers.
Tôliers = Sheet (plate) workers.
Portières = Doors.
Petits objets = Details.
Bureau = Office.
Ebénistes-Polisseurs = Cabinet makers-Polishers.
*Stone = réparation... électrique = Repairs to electrical lighting equipment.
Tournerie de roues = Wheel shop.
Roues réparées = Repaired wheels.
Roues à réparer = Wheels for repairs.

Explanation of Frenc
Pont roulant électrique 1 200 k travelling crane.
Tour = Lathe.
Ventilateur = Fan.
Bureau = Office.
Soudeurs = Welders.
Lower half
Menuiserie mécanique = Wood
Ajusteurs (serrures, charnières hinges).
Démontage = Stripping.
Gaziers = Gas workers.



✱ Stone = réparation de l'équipement électrique.

terms :
= 1.2-ton electric

orking machines.
= Fitters (locks,

Forge = Smithy.
Soudure électrique = Electric welding.
Ajusteurs (chauffage) = Steam heating fitters.
Pont roulant électrique 1 000 kg = 1-ton electric travelling crane.
Runway pour dynamo = Dynamo runway.
Runway pour caisses accum. = Battery box runway.
Palan électrique = Electric block and tackle.
Remorque = Trailer.
Vérin électrique = Electric jack.
Entrée des voitures = Vehicles—in.

Transbordeur = Traverser.
Chaine pr transformations = Belt for alterations.
Moteur = Motor.
Fosse pour mise en place caisses accum. = Pit for putting up battery boxes.
Groupe de soudure = Welding set.
Cabestan électrique = Electric capstan.
Stone = Electric lighting.
Magasin = Stores.
Acetylène = Acetylene.
Compresseurs = Compressors.
Chaufferie = Heating plant.

varied very considerably owing to the great differences in the work to be done; some of the stands require as many as 30 men at some moments, and then only 2 or 3 at others.

The organisation must, therefore, be most flexible so as to meet the needs of the belt without delay. The planning programmes, as described in the first part of this article, solved the problem.

The times to be allowed were another difficulty. The repairs to a vehicle depend much more on the capability of the workman than is the case with locomotive repairs ; there are many more unexpected repairs to be done and the work is more difficult to define.

There are, therefore, appreciable differences between the times allowed and those taken. Interference with the normal working of the belt has only been prevented by constant attention and by taking the necessary steps to deal immediately with emergencies.

The organisation of the stores was also full of difficulties. Except for a few parts in common use, stocks of spares cannot be formed. Each part differs from carriage to carriage. A part wanted today may not be wanted again for weeks. Another part has to be made especially from the dimensions of the parts beside it.

The secondary belts have to supply, within very short time allowances, and carriage by carriage, the whole of the spares wanted.

Thus, the saw mill, between stands 6 and 12, that is to say in two and a half days, has to prepare, mark off, and machine the pillars, rails, packings, hoop sticks, etc..., needed for repairs to the body framing.

Here again, it is essential that the time allowances are strictly adhered to at the secondary belts, as at the main one.

The whole of the difficulties were overcome thanks to the firm determination of the organising section to reach the desired objective. The carriage repair belt now works with the same regularity as the locomotive, boiler, and tender belts.

* * *

These examples of organisation we have briefly outlined show how successfully the principle of belt work has been applied at Malines to a branch of industry to which at first sight it hardly seems applicable.

The organisation of repairs to railway vehicles is in fact much more difficult than the industrial mass production of new parts wherein the work to be done is well defined and where everything can be anticipated, studied and calculated in advance.

In manufacturing industries, supplies can be stocked in advance and once the shop has been properly organised it continues to run almost automatically.

Locomotive and carriage repairs are quite another matter. Owing to the variety of types, the number of parts is enormous; the amount of wear varies vehicle by vehicle; even the materials from which the parts to be repaired were made originally are frequently not properly known.

The normal progress of the repair work is constantly being upset by the unexpected.

Materials and spares cannot be stocked in advance as the stock would be too great ; the frequent delays in obtaining supplies are always liable to disorganise the shop completely.

These few considerations show how complicated it is to organise the repairs to railway rolling stock ; it must be remembered too that, in spite of the variations in the kind and extent of the

repairs, the men must be kept fully employed.

These difficulties, both as regards labour and stores, were all overcome when the production offices were set up.

The belt system made it possible to get a clean and orderly shop, with each part in its proper place ; unnecessary transport is eliminated; there is no further waste of labour, either in looking for materials or in making fruitless journeys.

As all the time allowances have to be observed literally, the whole of the staff is kept fully busy the whole time.

The repair belts are now working with complete regularity; the fully repaired vehicles come off the belts mathematically to the hour laid down.

Finally, apart from the savings in labour and time vehicles are out of service, the quality of the work has steadily improved, thanks to it being possible to control it both systematically and strictly.

[621. 135.4, 625. 113 & 625. 215]

Transition curves.

Diagrams giving lengths of transitions, safe speeds and overturning speeds,

by P. H. JACKSON, A. M. Inst. C. E.

(The Railway Engineer.)

During recent years the introduction of transition curves on railways has become more and more general. Their use is beneficial in two ways : first, they greatly minimise the discomfort felt by passengers when entering a curve, particularly when the speed of the train is approaching the limit for which the curve is suitable : secondly, they help the trackmen to maintain a true alignment, as the side thrust on a curve is attained gradually, and the track is not pushed out of line at the commencement of the curve. In the early days of railways, the possibilities of transitions were not realised. Gangers, when they found their track getting knocked out of alignment, sometimes made an attempt to put in slight easements at the commencement of curves, and they may thus take credit for the introduction of the modern transition. Nowadays, it may be taken for granted that provision is made for the insertion of transitions when the centre line of a new railway is finally set out, but much work has still to be done in re-aligning old track, and it is hoped that the following notes may be of use to some of those engaged both on this work and on new railways abroad.

Figure 1 shows in graphic form the maximum safe speeds on curves, and the desirable lengths of transitions. The figures so obtained may be used for setting out new railways or for re-alignment work. As, however, the amount of slew in re-alignment is usually limited by a number of fixed structures, there has also been shown on this diagram the speed for which any length of transition on a curve of any radius is suitable. The diagram can be used for track of any gauge, and for 4 ft. 8 1/2 in. and 5 ft. 6 in. gauge should be used to its limit of 90 miles per hour, this speed seldom being exceeded in practice. For narrower gauges a suitable maximum speed may be selected as the limit, such as 60 m. p. h. for metre-gauge track.

The lengths of transitions given for the maximum safe speeds are sufficient, and as far as running is concerned, nothing is gained by making them longer. It must, however, be remembered when re-aligning existing track that a long transition usually needs a large slew, and, owing to the presence of fixed structures, it will often be found that the available length of transition is considerably less than is desirable. Money may sometimes be well spent in moving structures if the expenditure be not too great, but the introduction of a transition, however short, will always be found to result in improved running.

Explanation of figure 1.

The diagram is simple to read, and the following examples will show the method of use :

The parallel inclined lines across the diagram represent speeds in miles per hour and at the points where they meet the single inclined line (which will be referred to as the « speed limit » line) show the maximum safe speeds over curves of various radii. For example, if it is required to find the maximum safe speed over a curve of 1 500-ft. radius, follow the 1 500-ft. radius line and it will be found to intersect the « speed limit » line close to the point where the

latter is met by the 52-m.p.h. line, thus showing that the maximum safe speed over a curve of this radius is 52 m.p.h. Similarly it will be seen that the maximum safe speed over a curve of 3 000-ft. radius is 73 m.p.h.

If it is now required to find the correct length of transition in the first of the two previous examples, follow the 1 500-ft. radius line and it will be found to cut the « speed limit » line close to the vertical line representing a transition 320 ft. in length, showing that on a 1 500-ft. curve, the transition should be 320 ft. long. It may be, however, that owing to limits of slew, it is possible to provide a transition only 170 ft. long in this particular case. Look for the point at which the 170-ft. transition line cuts the 1 500-ft. radius line. This will be found to be close to the 42-m.p.h. line, showing that a transition 170 ft. long on a curve of 1 500-ft. radius is correct for a speed of 42 m.p.h., and in the circumstances this may be considered the best improvement possible. Going back to the second example, and following the 3 000-ft. radius line, it will be found that the correct length of transition for a curve of this radius is about 450 ft.; and if it is possible to provide a transition only 200 ft. long, this length is suitable for a speed of 56 m.p.h.

It will be seen from the diagram that with a maximum speed of 90 m.p.h. the correct length of transition increases as the radius increases up to 4 500 ft., this radius needing a length of about 550 ft. Beyond this point the length decreases as the radius increases. On a curve of 6 000-ft. radius, for example, the transition should be 410 ft. long, and the correct length for a curve of 9 000-ft. radius is 270 ft.

It is not, of course, suggested that trains should not run over short transitions at the maximum safe speed for which the circular curve is suitable. As previously mentioned, even a short transition will result in improved running, but every effort should be made to introduce one of the correct length, and if this is done it will be found that when running at high speeds it is impossible to feel the point at which the curve commences, always assuming that proper cant is provided. It is, perhaps, hardly necessary to mention that a transition is needed at both ends of a curve — not only at the leading end.

In order to use the diagram for narrower gauges it is necessary, as previously mentioned, to make use of the maximum speed at which trains run on the gauge in question. If this is not done, the transition will often be unnecessarily long. Assuming a maximum speed of 60 m.p.h. for metre-gauge track, the correct length of transition for all curves up to 2 000-ft. radius will be identical with the length required for 4 ft. 8 1/2 in. gauge. Beyond this radius, however, the correct length is considerably less. On a curve of 6 000-ft. radius it is only about 125 ft. instead of 410 ft., the reduction being due to the decreased maximum speed.

Reverse curves.

Turning now to the question of reverse curves, there is usually no need to insert a short length of straight road between the transitions. If this is done, the result is that the transitions are reduced in length, making them less efficient, and there is no compensating advantage.

In the case of reverse curves of unequal radii, if the sharper curve is of less radius than 4 500 ft. (or the corresponding critical radius for narrower gauges, such as 2 000 ft. for metre gauge), there is no real necessity to make the transition to the easier curve suitable for its maximum speed. Assuming that reverse curves have radii of 1 000 and 2 000 ft., it will be seen from the diagram that the sharper curve needs a transition 260 ft. long, and has a maximum safe speed of 42 m.p.h. (There

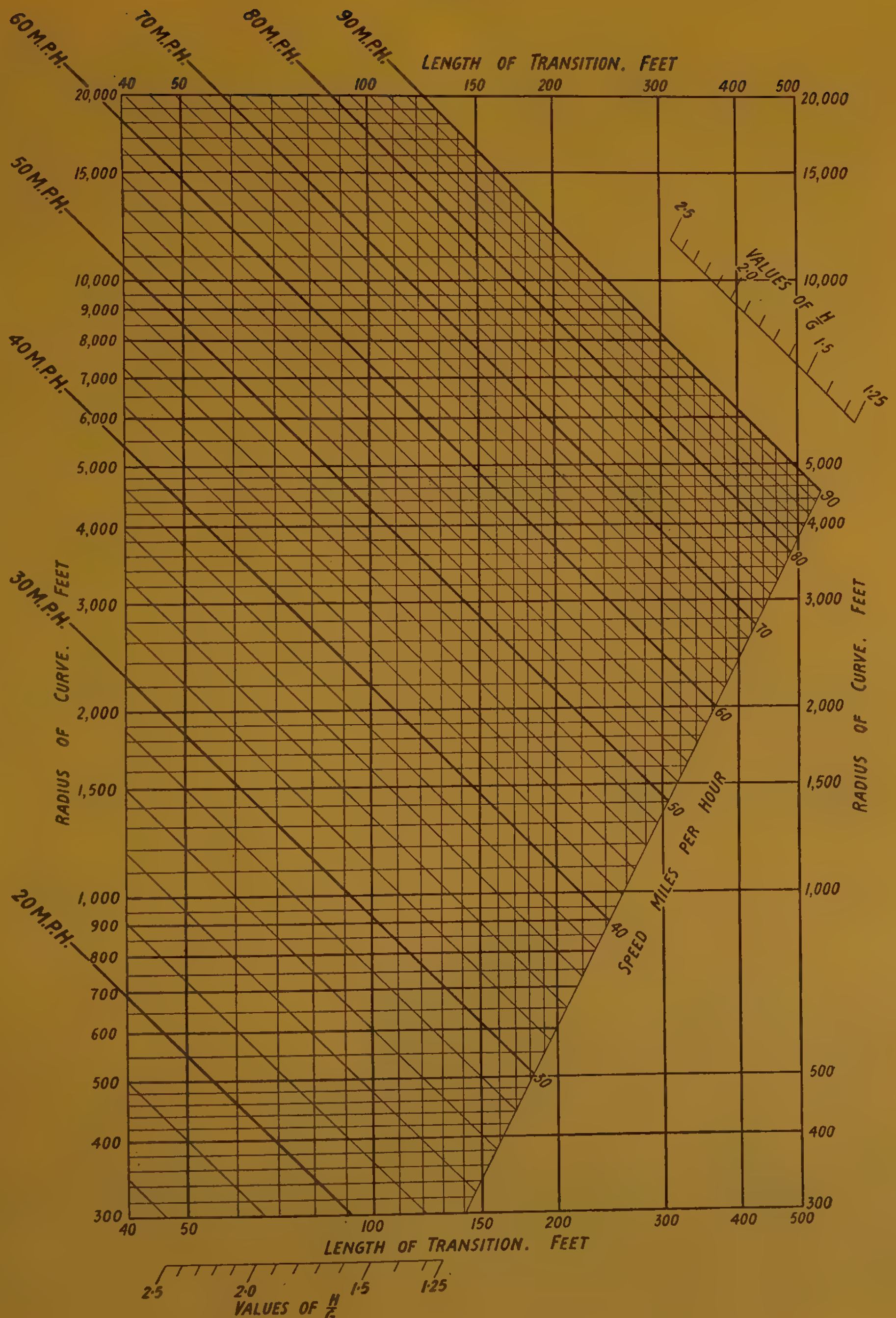
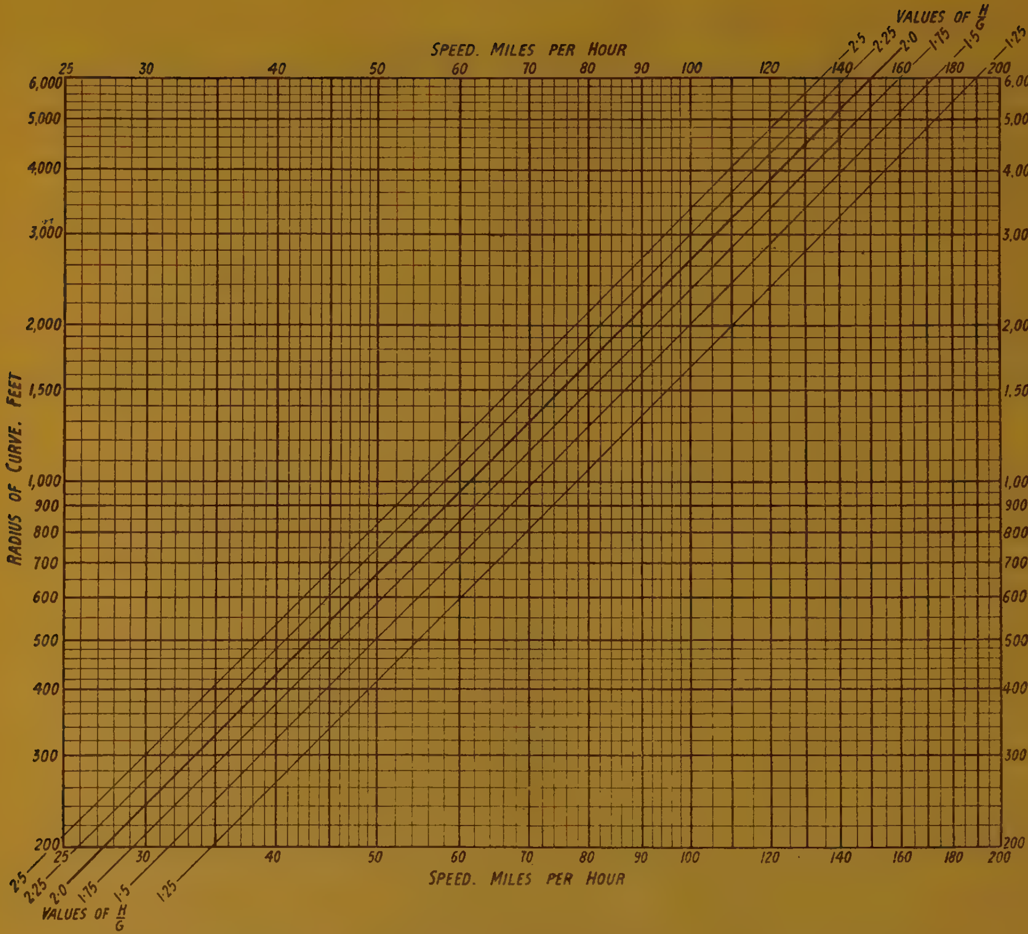
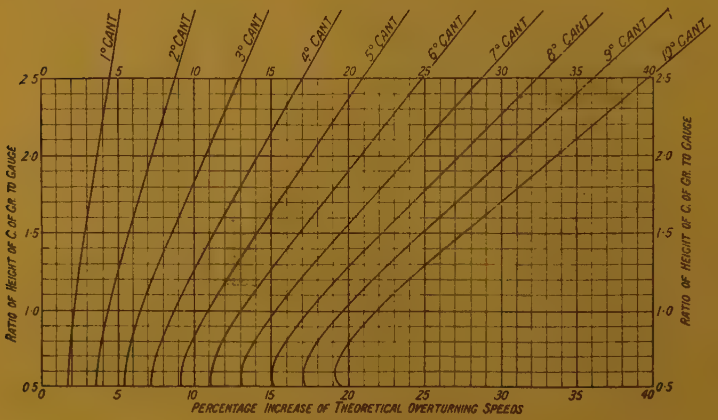


Fig. 1. — Lengths of transition curves for various speeds and radii.





Above : Fig. 2. — Theoretical overturning speeds on a track without cant for certain values of $\frac{H}{G}$.

Left : Fig. 3. — Percentage increase of theoretical overturning speeds for varying amounts of cant.

is probably a permanent speed restriction in force.) The easier curve has a maximum safe speed of 60 m.p.h. and would normally need a transition about 360 ft. long, but such a length is obviously unnecessary in this case, and a transition 130 ft. long, suitable for about 42 m.p.h. (the maximum speed over the sharper curve), is all that is required. A considerable slew can thus often be saved. In cases where it is not possible to get the proper length of transition to each of the curves, they should be arranged so that they are both suitable for the same speed.

It sometimes happens that the radius sharpens part of the way round a curve. When the alteration is appreciable a transition should be inserted connecting the two portions of the curve. Its length may be ascertained from the following formula : $E = \dfrac{R\,r}{R - r}$ where R and r represent the large and small radii respectively, and E is an equivalent radius for which the transition may be made suitable. For instance, if a curve of 3 000-ft. radius sharpens to 2 400 ft., the formula gives

$$E = \frac{3\,000 \times 2\,400}{600} = 12\,000$$

The transition should therefore be the same length as for a plain curve of 12 000-ft. radius, if possible. Reference to the diagram will show this length to be about 200 ft.

Cant.

The provision of suitable cant is a matter of importance. The principal effect of cant is to lessen the discomfort felt by passengers when passing round a curve, and the comparatively small increase in safety obtained by its use (at least in the case of vehicles having a low centre of gravity) is not always realised. If necessary, the cant on any curve may be as little as one half of the theoretical amount needed for the average maximum speeds worked over that curve, but as a rule it should not be less than that amount, and it is a common practice to make the cant about 75 or 80 % of the theoretical amount. Cant should never be excessive : too little is better than too much. Generally speaking, it should not be greater than about one tenth of the gauge, that is, not greater than the following amounts : 5 ft. 6 in. gauge, maximum cant 7 inches; 4 ft. 8 1/2 in. gauge, maximum cant 6 inches; and metre gauge, maximum cant 4 inches.

Exceptions may sometimes be made in the case of sharp curves over which trains always run at high speed and where there is no risk of any vehicle coming to rest on the curve.

Cant gradient.

Care must be taken to ensure that the cant gradient on a transition *(i.e.,* the rate at which the cant on the outer rail is attained relatively to the inner rail) is not too great for the speed of traffic over the curve. A good rule for cant gradient is given by the formula :

$$\text{Maximum cant gradient} = \frac{50V}{G}$$

in which V is the maximum speed in miles per hour actually attained on the curve, and G is the gauge in feet. This gives the following approximations for practical use : 5 ft. 6 in. gauge — maximum cant gradient = 9V; 4 ft. 8 1/2 in. gauge — maximum cant gradient = 10V; and metre gauge — maximum cant gradient = 15V.

Thus on 4 ft. 8 1/2 in. gauge track the cant gradient on a curve over which the highest speed attained is 75 m.p.h. should not be steeper than about 1 in 750. An absolute maximum of 1 in 300 for 4 ft. 8 1/2 in. gauge and 1 in 450 for metre gauge should never be exceeded, but will

be found sufficiently easy for speeds of about 30 m.p.h. There is, of course, no limit in the other direction, and it may sometimes be found convenient to increase the cant by a given amount for each rail length, such as three quarters of an inch for 60-ft. rails, equivalent to a cant gradient of 1 in 960. This is easy for gangers to remember when there are no centre line monuments with the cant marked on them.

It will be found that in the case of transitions which are the correct, or nearly the correct, length for maximum speeds, the resulting cant gradients are not steeper than the limits of the abovementioned formula. A certain amount of difficulty, however, will sometimes occur in dealing with transitions which are considerably shorter than the standard length. For instance, it may happen that on a curve of 3 000-ft. radius on 4 ft. 8 1/2 in. gauge track, it is possible to get a transition only 150 ft. long. The curve might need a cant of 4 1/2 inches, giving a cant gradient of 1 in 400. This is too steep for fast running such as might be expected on a curve of this radius, and every effort should be made to increase the length of transition, even at the expense of a slight reduction of radius. If the radius is reduced to, say, 2 800 ft. for a short distance it may be possible to lengthen the transition to 200 ft., and with a reduction of cant to 4 inches, a cant gradient of 1 in 600 is obtained, which may be sufficiently good if the maximum speed is not greatly in excess of 60 m.p.h. Each case must be treated on its merits, and when the radius is reduced in order to lengthen the transition, care must be taken not to reduce it below that necessary for the maximum speed worked over the curve.

In the case of reverse curves there must, of course, be no cant at the point of reversal, and if the curves are of unequal radius and the transitions are both suitable for the same speed it will be found that the cant gradient is the same on each curve. It is sometimes suggested that cant should be built up on the straight when it is not possible to put in a transition. This is not good practice, though occasionally it may be necessary as a last resort, and in cases which are cited it will usually be found that a transition of some kind does exist. After a curve has been re-aligned there are frequently small variations in radius, and the cant is sometimes adjusted correspondingly. In these cases it is better to keep a constant cant throughout. This simplifies the ganger's work, and such small changes of cant are not justified as they are more than counteracted by differences of speed.

Speed limit.

The speed at which a vehicle may be allowed to pass round a curve is influenced considerably by the height of its centre of gravity. In this country the ratio of this height to the gauge of the track (a ratio which will be referred to as $\frac{H}{G}$) is not greater than about 1.25 to 1 in the case of locomotives and other vehicles which travel at high speed. The « speed limit » line in figure 1 has therefore been calculated for this value, but in order that the diagram may also be used on railways where the ratio is greater, two scales giving values of $\frac{H}{G}$ up to 2.5 have been placed near the ends of the « speed limit » line. A straight line drawn between the appropriate points on these scales will provide a new « speed limit » line in figure 1 has the- maximum safe speeds necessitated by the altered conditions. For instance, if $\frac{H}{G} = 2$, a line joining these points shows that the safe speed on a curve of 1 500 ft.

radius is reduced from 52 to 41 m.p.h. In consequence of this reduction of speed, the length of transition is shown to be reduced from 320 to 155 ft., but for obvious reasons the standard length of 320 ft. should be put in when possible, the new « speed limit » line being used only for the lower safe speed. Conversely, a value of $\frac{H}{G}$ less than 1.25 will give higher safe speeds but the line on the diagram should be used in these cases, as it represents the highest speeds which are normally run over curves of various radii in this country and probably represents the reasonable limit of safety. Moreover, with a moderately high centre of gravity, overturning may be expected to take place before climbing, but as the height of the centre of gravity is reduced, the possibility of climbing comes into greater prominence.

Diagram No. 2 shows theoretical overturning speeds on a track of any gauge without cant for certain values of $\frac{H}{G}$. Diagram No. 3 gives the percentage to be added to these overturning speeds for varying amounts of cant, shown in degrees in order to make the diagram applicable to any gauge. On 4 ft. 8 1/2 in. gauge a cant of 6 degrees is equivalent to a cant of 6 3/16 inches.

On curves without cant the « speed limit » lines on diagram No. 1, including those which may be drawn between any points on the scales already mentioned, give speeds which are about 55 % of the theoretical overturning speeds shown on diagram No. 2.

In figure 1 the radius scale is taken down to 300 ft., but in order to allow for the rigid wheelbase of locomotives, and other factors which may affect speed on sharp curves, it is suggested that so far as safe speed is concerned the diagram should be used with caution when the radius is less than one hundred times the gauge in question, the permitted speed being less than that shown.

It has, of course, been assumed thoughout that the curves dealt with are plain curves without the added complication of switches and crossings, and that maintenance of the track is in accordance with the best British practice. The latter point is of special importance when the centre of gravity of vehicles is exceptionally high and their cross section is unusually large compared with the gauge of the track. In these cases any irregularities of alignment or level are apt to set up dangerous rolling, which is difficult to stop. The provision of proper transitions and regular cant gradients will promote smooth running and reduce the wear of both track and vehicles. As previously mentioned, transitions should if possible always be the standard length, even if this does not seem necessary on account of the present speed of traffic, but there is no need to adhere exactly to the length shown on the diagram; a few feet one way or the other will make little difference.

With regard to the actual work of re-alignment, the method described by Mr. W. H. Shortt in the Institution of Civil Engineers *Selected Engineering Papers* No. 3 is recommended. This is a quick and accurate method. The length of transition in any proposed re-alignment can be seen at once, and the necessary alterations are easily made. One engineering assistant and two chainmen can survey an existing curve, the improvement can be drawn on a piece of squared paper in the nearest signal-box or platelayers' hut without the aid of drawing instruments, and the new alignment can be pegged out on the ground and checked the same day. Mention should also be made of Mr. Shortt's original paper, published in the *Proceedings of the Institution of Civil Engineers*, Volume CLXXVI, from which much useful information may be obtained.

[621 .132.3 (.42)]

London and North Eastern Railway three-cylinder eight-coupled passenger locomotive.

We reproduce hereafter, from *The Engineer*, further particulars about the 2-8-2 passenger locomotive « Cock o' the North », built to Mr. H. N. Gresley's design. A short description of this engine was given in the June 1934 issue of this *Bulletin*.

It has been constructed to deal with the heavy section of the London and North-Eastern Railway between Edinburgh and Aberdeen, and hauls the East Coast day and night expresses. The principal particulars are given in the weight diagram and in the table, and need not be recapitulated here.

Mr. Gresley does not hesitate to acknowledge the influence of recent French designs, particularly of the latest Paris-Orleans passenger engines. The first cylinders were designed for piston valves, whereas those actually fitted have, as shown by our drawings and engravings, double-beat poppet valves, which are operated by the « A.L.E.R.C. » gear. The valves and gear were supplied by Associated Locomotive Equipment, Ltd., but the cylinder block — a complicated piece of work weighing nearly 7 tons — was cast at the Gorton works of the London and North-Eastern Railway. In passing, we may mention that it is Mr. Gresley's present intention to fit piston valve cylinders in a second engine identical in other respects.

The symmetry of the design of the cylinder block cannot fail to be observed. It is, in fact, the result of intention, for a symmetrical design is always easier to cast than an unsymmetrical one, but the placing of the twelve valves in line very greatly simplified the valve-operating mechanism, which is contained in two separate cam-boxes, one for each side of the engine, and separately driven by universal shafting connecting with gears carried on return cranks on the main crank pins. In the drawing of the

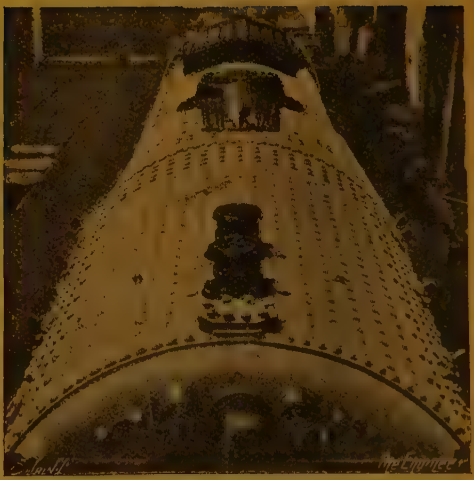
cylinders the end of the tunnel which contains one of the cam-boxes is marked, and the facing strips on which the mechanism rests will be observed.

From what has been said it will be understood that two cam shafts are employed to operate the twelve poppet valves. The cams are mounted on the shafts, and the points of cut-off and also reversal are effected by moving the cam shafts endwise by means of rack and pinion gears.

The valve chests for the outside cylinders are arranged in the manner usual

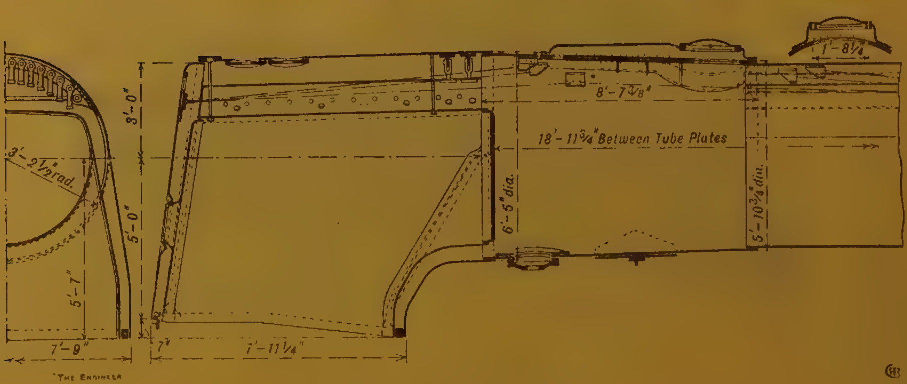
Left side cam box.

Cylinder and valve chests.

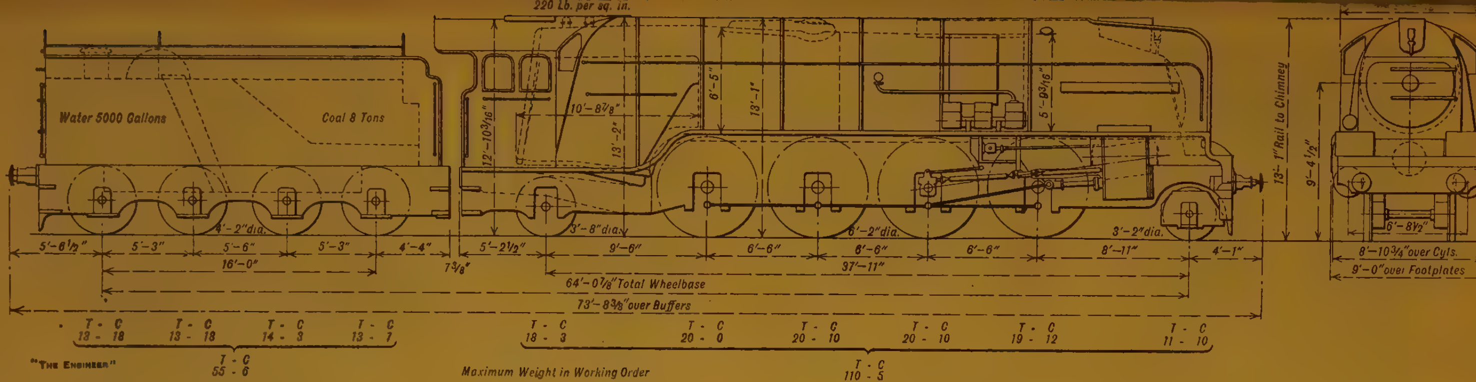


Top view of boiler.

The boiler.



Longitudinal section of boiler.



Grate :

Length of slope	7 ft. 2 in.
Width	6 ft. 11 3/4 in.
Grate area	50 sq. ft.

Fire-box :

Height of crown above foundation ring :	
Front	6 ft. 8 13/16 in.
Back	6 ft. 0 5/16 in.
Interior, length at top	9 ft. 2 3/4 in.
Interior, width at boiler centre	5 ft. 4 1/2 in.
Thickness of copper plates:	
Sides and back	9/16 in.
Tube plate	9/16 in. and 1 1/4 in.

Boiler :

Outside length, fire-box overall	10 ft. 8 7/8 in.
Outside length, fire-box at bottom	7 ft. 11 1/4 in.
Outside width, fire-box at bottom	7 ft. 9 in.
Diameter of barrel, maximum	6 ft. 5 in.
Length of barrel	19 ft.
Thickness of barrel plates	23/32 in. and 25/32 in.
Thickness of wrapper plates	9/16 in.
Length of smoke-box at bottom	8 ft. 11 in.

Tubes, small :

Material	Steel
Number	121
Diameter outside	2 1/4 in.
Thickness	10 I.W.G.

Tubes, superheater flue :

Number	43
Diameter outside	5 1/4 in.
Thickness	5/32 in.
Length between tube plates	18 ft. 11 3/4 in.

Heating surface :

Fire-box	237 sq. ft.
Tubes, 2 1/4 in.	1354.2 sq. ft.
Flues	1122.8 sq. ft.
Total evaporative H.S.	2714.0 sq. ft.

Superheater :

Number of elements	43
Diameter inside	1 1/64 in. F.
Heating surface	635.5 sq. ft.
Total heating surface	3349.5 sq. ft.
Two Ross pop safety valves	3 1/2 in. diam.
Working pressure	220 lb. per sq.in.

Axles :

	Diam. Length.
Journals, pony	6 1/2 in.×9 in.
Journals, coupled	9 1/2 in.×11 in.
Journals, trailing	6 in.×11 in.
Crank pins, outside	6 3/4 in.×6 in.
Crank pins, inside	9 1/4 in.×6 in.

Coupling pins :

Leading	4 3/4 in.×4 in.
Driving	7 1/2 in.×4 1/2 in.
Intermediate	4 3/4 in.×5 in.
Trailing	4 3/4 in.×5 in.

Springs : Pony : helical, 10 3/16 in. long free, 5 1/2 in. outside diameter, Timmis section. Coupled wheels : laminated, 3 ft. 6 in. centres, 15 plates, 5 in. wide by 1/2 in. thick. Trailing wheels : laminated, 4 ft. 6 in. centres, 14 plates, 5 in. wide by 5/8 in. thick.

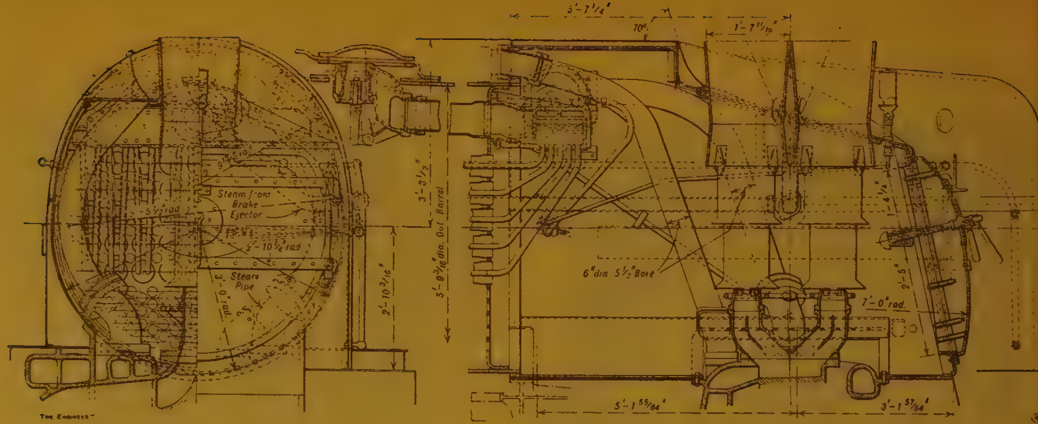
Cylinders :

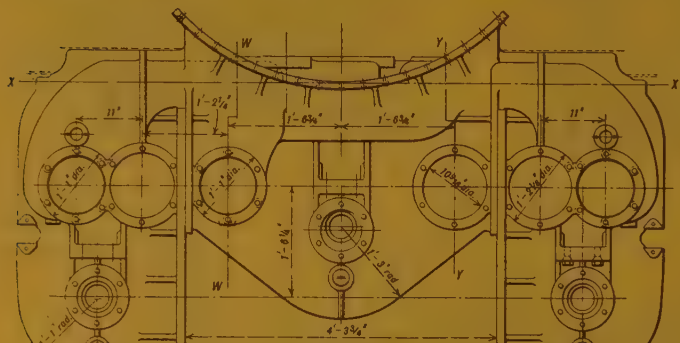
Number (21 in. diameter by 26 in. stroke)	Three
Cylinder horse-power	2 617

Motion :

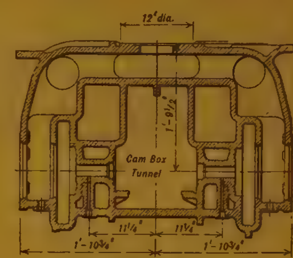
Type	Rotary cam.
Type of valves	Poppet.
Diameter of valves, steam	8 in.
Diameter of valves, exhaust	9 in.
Cut-off in full gear	70 %
Tractive effort at 85 % boiler pressure	43 462 lb.
Total adhesive weight	180 544 lb.
Adhesive weight ÷ tractive effort	4.15

Vacuum brake.

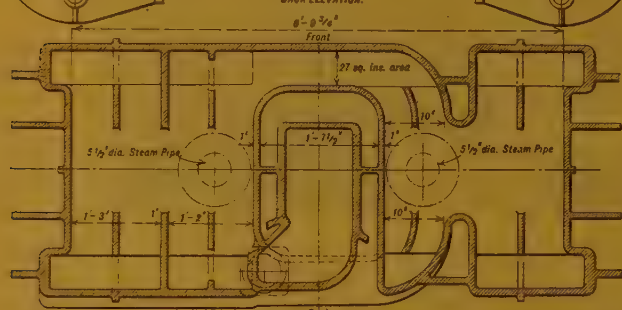




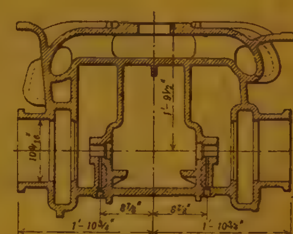
BACK ELEVATION.



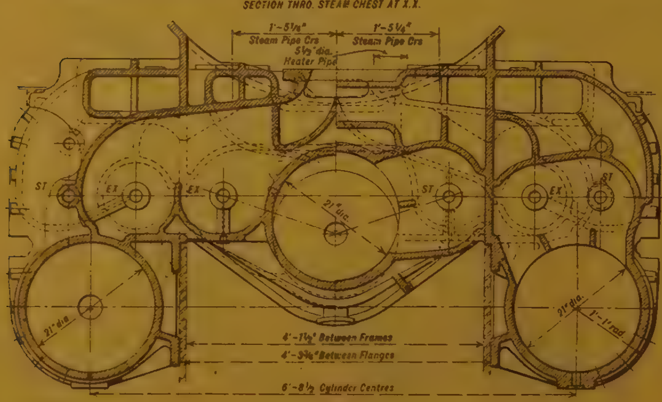
SECTION THRO. MIDDLE STEAM VALVE ON W.W.

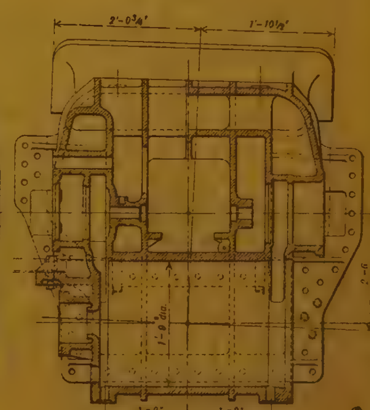


SECTION THRO. STEAM CHEST AT X.X.



SECTION THRO. MIDDLE EXHAUST VALVE ON Y.Y.





with « R.C. » poppet valve equipment — that is, each outside cylinder is fitted with four poppet valves, two at each end, one of which is for steam inlet and one for exhaust. For the centre cylinder the steam and exhaust valves are arranged on either side of the cylinder barrel. Those on the left hand are for the admission of steam, whilst those on the right hand are for the exhaust.

The cam shaft on the left hand, therefore, carries the steam inlet cams for the outside cylinder on that side of the engine and also for the centre cylinder, and, in addition, the exhaust cams for the outside cylinder, whilst on the right-hand side the cam shaft is fitted with the exhaust cams for the centre cylinder and for the outside cylinder, and the steam admission cams for the outside cylinder.

The position of the exhaust and admission valves will easily be seen by reference to the drawings, as they can be distinguished by the difference in diameters, the steam valves being smaller than the exhaust.

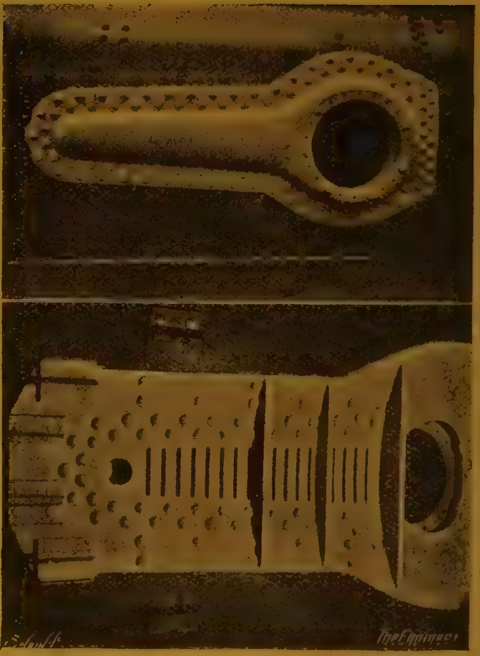
At the top of the cylinders a large steam receiver is formed in the casting, as shown clearly by the drawings, and steam is brought to it from the superheater header through two pipes inside the smoke-box.

The exhaust from each of the cylinders enters a common chamber in the centre of the casting, whence it passes through two blast nozzles, one placed at the base of each of two funnels, the arrangement of which can be seen in the drawings and photographs. Immediately above each exhaust nozzle there is a short tube, or petticoat, made of thin plate, which contains a group of four tubes of the same length so disposed and so shaped that they form in plan a pattern which is described by Mr. Gresley as a four-leaved clover. Immediately above the divided petticoat and between this and the base of each chimney is placed a further petticoat pipe, which is just a plain cylindrical piece without subdivisions. The exhaust nozzles are fitted with four wedge pieces disposed radially round the orifice with their apices downwards. The purpose of these wedges is to split the exhaust jet as it leaves the blast orifice, while, at the same time, they provide means for adjusting the area of the exhaust nozzle, this being done by shortening these projecting pieces, or putting in longer ones if necessary. This arrangement is known as the « K.C. » blast pipe, and was developed on the Paris-Orleans Railway, on which railway, as well as others, it has been very largely used with marked success.

In the drawings, another interesting detail calls for special attention. With the increase in size of locomotives, and the limitation set by tunnels, the problem of avoiding wet steam has been greatly increased, for there is no possibility of employing a steam dome. The usual practice is to fit a long pipe with many saw cuts through its upper part almost close up against the crown of the boiler barrel. In the « Cock o' the North » a departure has been made from this practice. The dome still exists, but is little more than a dished plate with a seating for the manhole cover. A view of it as seen from above is given, with another view showing the corresponding part inside the boiler. It will be noticed that a number of transverse slots are cut right through the shell plate, through which steam can find its way to the « dome ». The total area of the slots is much more than that of the regulator valve, and since the slots are in direct communication with the steam space, there is no place where water can lodge. It will be interesting to see if this arrangement solves one of the problems of the designer of large locomotives.

The regulator valve itself is shown in the drawing, and calls for no special comments except to note its large dia-

meter. The main steam pipe is 7 inches in diameter, and the pressure drop between the boiler and valve chest will, it is hoped, be in consequence small. Another illustration, of the top of the boiler, shows the dome, with, in front of it, the A.C.F.I. feed-water heater, and at the back, where they come actually within the cab, the two safety valves. None of these parts are visible in the general view of the engine, for the casing, as shown in one of the drawings, is excentric, giving the locomotive a level top from end to end. On the right there is, however, a small protuberance at one side where the pipes pass down to the feed pumps. We may mention here that the front of the cab is « veed », thereby giving space for much larger windows than the 3-inch vertical strips which are so often found in large locomotives. Those who are familiar with Mr. Gresley's « No. 10 000 », will recognise the form of front end determined by Dr. Dalby at the City and Guilds (Engineering) College.



The dome and steam drier.

The copper fire-box.

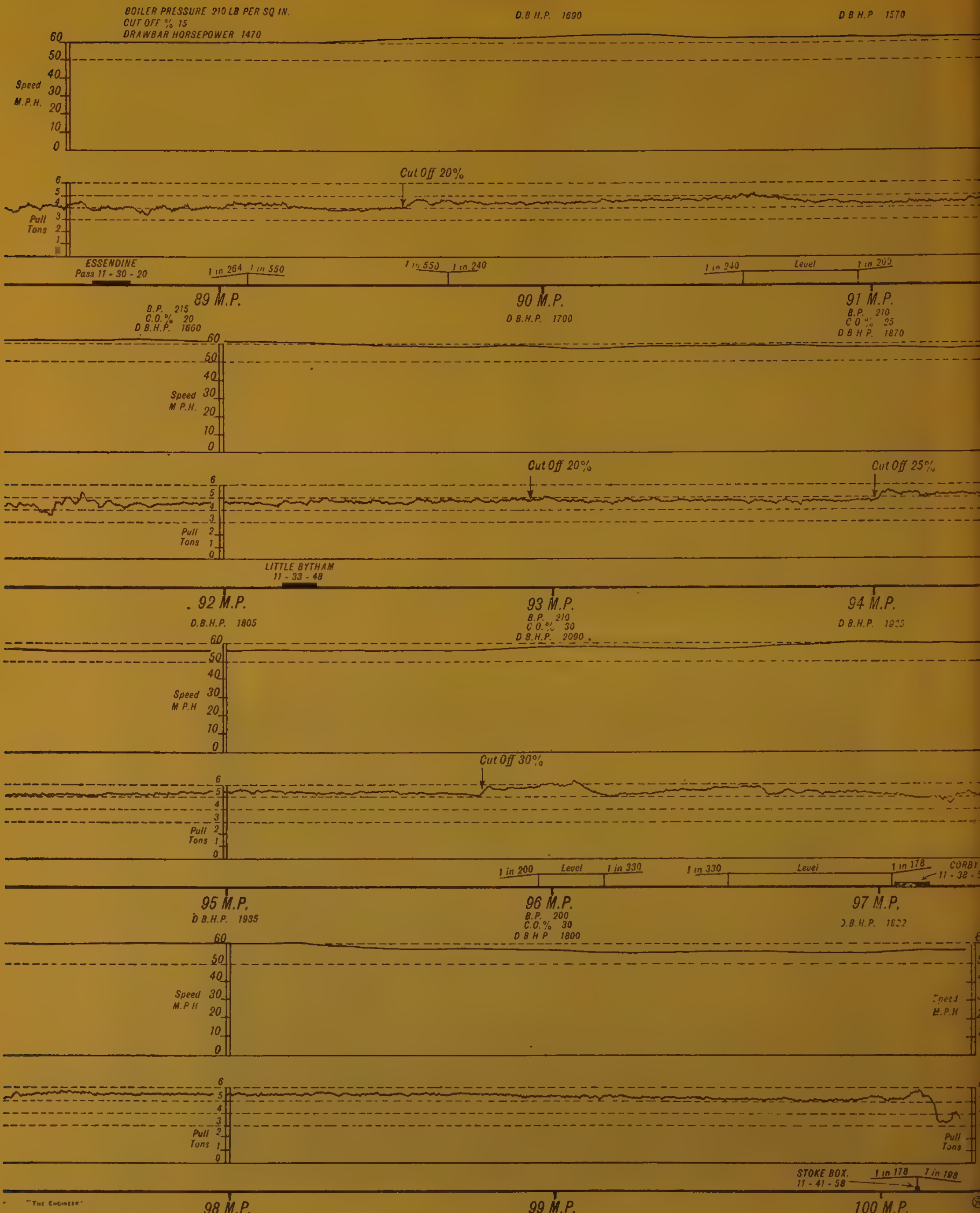
The boiler barrel is standard with the L.N.E.R. *Pacific,* but the fire-box itself is materially larger and is a magnificent piece of copper work. It is worth recording that whilst Mr. Gresley has never used flexible stays, he has never had any stay breakages in the large fireboxes of his *Pacifics.* The superheater is worth observing. In order to secure the large area it is of the « sine wave » type.

The tender is the same design as that fitted to the latest L.N.E. Railway *Pacifics.*

Dynamometer tests.

The new engine « Cock o' the North » was tested on June 19th, 1934, with a train of nineteen vehicles, including the dynamometer car, the total weight being 649 tons. The following log of the run, with a copy of the most interesting part of the chart, has been sent to us by Mr. Gresley.

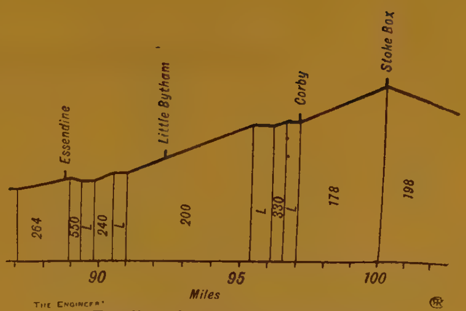
The train was started easily at King's Cross, the initial draw-bar pull being 14 tons. The cut-off was reduced to 45 % 750 yards from the start, the speed then being 20 m.p.h. on the gradient of 1 in 105. Two miles from the start the speed was 32 1/2 m.p.h.; 4 1/2 miles from the start the 8-mile gradient of 1 in 200 was reached, the speed at the foot being 58 m.p.h., with a 5-ton draw-bar pull, equivalent to 1 730 draw-bar horse-power. The cut-off was 20 %, but was increased to 22 % about half-way up the bank. The boiler pressure never fell below 195, and the speed at the top was 50 1/2 m.p.h. Hatfield, the first booking point, was reached in 22 1/2 minutes at a speed of 70 m.p.h., the usual time allowed being 26 minutes. No special demands were made on the locomotive between here and Hitchin the next booked point; 14 minutes were allowed and 13 1/2 taken, about 1 300 horse-power being given out at the draw-bar. Between Hitchin and Huntingdon North the effort required was relatively light, and the cut-off was reduced to 10 %, this enabling a pull of 2 1/2 tons to be exerted on the level at 70 m.p.h., equivalent to 1 050 horse-power at the draw-bar. After Huntingdon the cut-off was increased to 15 % to negotiate the 3-mile gradient of 1 in 200. The speed at the top of this was 53 m.p.h., the pull 4.2 tons, and the horse-power at the draw-bar 1 330. The cut-off was then eased to 10 % and would have remained so until Peterborough, but two bad permanent-way checks necessitated the cut-off being increased to 30 %. Starting from Peterborough a pull of 16 1/2 tons was recorded, falling to 12 tons at 10 m.p.h. The engine was progressively notched up, the 20 % position being reached when the speed was 33 m.p.h. On the 2-mile gradient of 1 in 264 near Essendine, the speed did not fall below 60 m.p.h. A pull of 4.1 tons was given at this speed, equivalent to a draw-bar horse-power of 1 470. The gradient of 1 in 200 near Little Bytham is about 5 miles long, and for about the first half of the distance the cut-off was 20 %, 1 700 horse-power being obtained at a speed of 58 m.p.h. The cut-off was increased to 25 %, and in this position a pull of 5.4 tons was given at 56 m.p.h., corresponding to 1 800 draw-bar horse-power. The boiler pressure varied between 210 and 215. Near the top of the bank, at the same speed, the cut-off was increased to 30 %, and on the short stretch of level a pull of 6.1 tons was exerted at a speed of 57 1/2 m.p.h., corresponding to a horse-power of 2 100 at the draw-bar. After Corby, there is a gradient of 1 in 178 for 3 miles, and the speed at the foot of this was 60 1/2 m.p.h. The engine climbed this in 30 % cut-off, the speed at the top being 56 1/2 m.p.h. The pull remained very steady, being 5.4 tons at the 98th mile post at a speed of 60 m.p.h., corresponding to 1 930 draw-bar horse-power. A reproduction of the dynamometer car record on this section is attached. The remain-



L. N. E. Ry. locomotive, « Cock o' the North ». — Dynamometer chart.

der of the distance to Grantham is on falling gradients, the time allowed from Peterborough is 34 1/2 min., and 2 1/2 min. were gained. From Grantham to Barkston is also on falling or easy gradients.

The engine and train were turned on the triangle at Barkston, which is on a gradient of 1 in 200, the starting pull required being 14 1/2 tons. The engine was put into 40 % cut-off half a mile from the start, and at the end of the first mile the speed was 26 m.p.h., the pull was 8.35 tons, and the draw-bar horse-power 1 295. The engine was put into 15 % cut-off about 2 miles from the start, and kept there till about three-quarters of a mile past Grantham, being then increased to 20 % in readiness for the 5-mile gradient of 1 in 198. The draw-bar horse-power on this gradient varied from 1 415 to 1 490. The speed at the foot of it was 49 m.p.h., falling to 45 m.p.h. at the top, with a boiler pressure of 210 lb. The succeeding 10 miles are all on falling gradients, mainly 1 in 178 and 1 in 200. Steam was shut off on these, and the engine put into mid-gear, and in this position the poppet exhaust valves were held of their seats, resulting in a free-running engine. The speed at the top of the gradient was 60 m.p.h., and there was little variation in this speed when coasting. Owing to the nature of the line, very little effort was required for the remainder of the distance to Peterborough. The starting pull at Peterborough rose to 16.3 tons. About 2 miles from the start the engine was put into 12 % cut-off, being increased to 15 % after a further 2 miles. It was kept at this except for about 3 miles at Abbots Ripton, where it was increased to 20 %. No very large horse-powers were recorded before reaching Huntingdon; after speed had been attained they varied between 1 270 and 1 515. Approaching Huntingdon the cut-off was reduced to 12 % and left at



Profile, Essendine to Stoke.

that for about 20 miles, being increased to 18 % near Biggleswade. On the gradient of 1 in 330 shortly after passing there, the draw-bar horse-power was 1 667 at a speed of 62 1/2 m.p.h. On the gradient of 1 in 200 before Hitchin the cut-off was increased to 25 %, and a pull of 4.9 tons obtained at 61 1/2 m.p.h., equivalent to 1 800 horse-power at the draw-bar. Twenty-seven minutes were allowed between Huntingdon and Hitchin, and two were gained. The 4-mile gradient of 1 in 200 after Hitchin was climbed in 30 % cut-off, the best horse-power recorded at the draw-bar being 2 100 at a speed of 60 m.p.h., the draw-bar pull being 5.9 tons. After this gradient was surmounted, very little further effort was required to Hatfield, but a permanent way caution near Knebworth required steam to be shut off, the speed being reduced to 34 m.p.h., requiring the engine to be worked for a short way in 40 % and 30 % cut-off, this being reduced to 12 % after about 2 miles. The cut-off was increased to 20 % for a short distance after leaving Hatfield, and 1 690 draw-bar horse-power registered. After that only relatively small efforts were required, and steam was shut off about 3 miles after Potters Bar, King's Cross being reached in one minute under the allowed time from Hatfield.

[621. 132. 8 (.86)]

A multi-engined steam locomotive.

(From *The Engineer.*)

It was with very particular interest that we availed ourselves of an offered opportunity to visit the Shrewsbury Works of the Sentinel Waggon Works, Ltd., and to see two of the three locomotives that the firm has built to the order of the Société Nationale de Chemins de fer en Colombie, South America. We were unable to see all three, since one of the locomotives has been undergoing trials of a very satisfactory nature in Belgium, on the metre-gauge lines of that country. These three locomotives, which are all precisely similar, are of exceptional interest owing to the departure that has been made from « traditional » locomotive practice. They are intended for heavy haulage work on a railway with steep gradients and curves of small radius, and are, we understand, to be the prototype of a range of similar locomotives on two, three, and four axles. For this reason the various parts have been standardised as far as possible.

In the particular locomotives about to be described a six-axle arrangement was adopted for two reasons. The Colombian railways are built with light-gauge rails, so that axle loading must be kept down. At the same time, the severe gradients require that the locomotives shall be able to exert a high tractive effort. Since on these machines every axle drives, a multiplicity of axles became desirable, not only to spread the weight, but also to obtain the high tractive effort. Reference to the half-tone

Fig. 1. — Six-engined steam locomotive on trial.

engravings given herewith will indicate at once how great is the departure from normal locomotive design. There are no coupled wheels; all the axles are accommodated in bogies; and visible cylinders and valve gear are conspicuous only by their absence. Moreover, the chimney appears to rise from the very centre of the boiler.

General design.

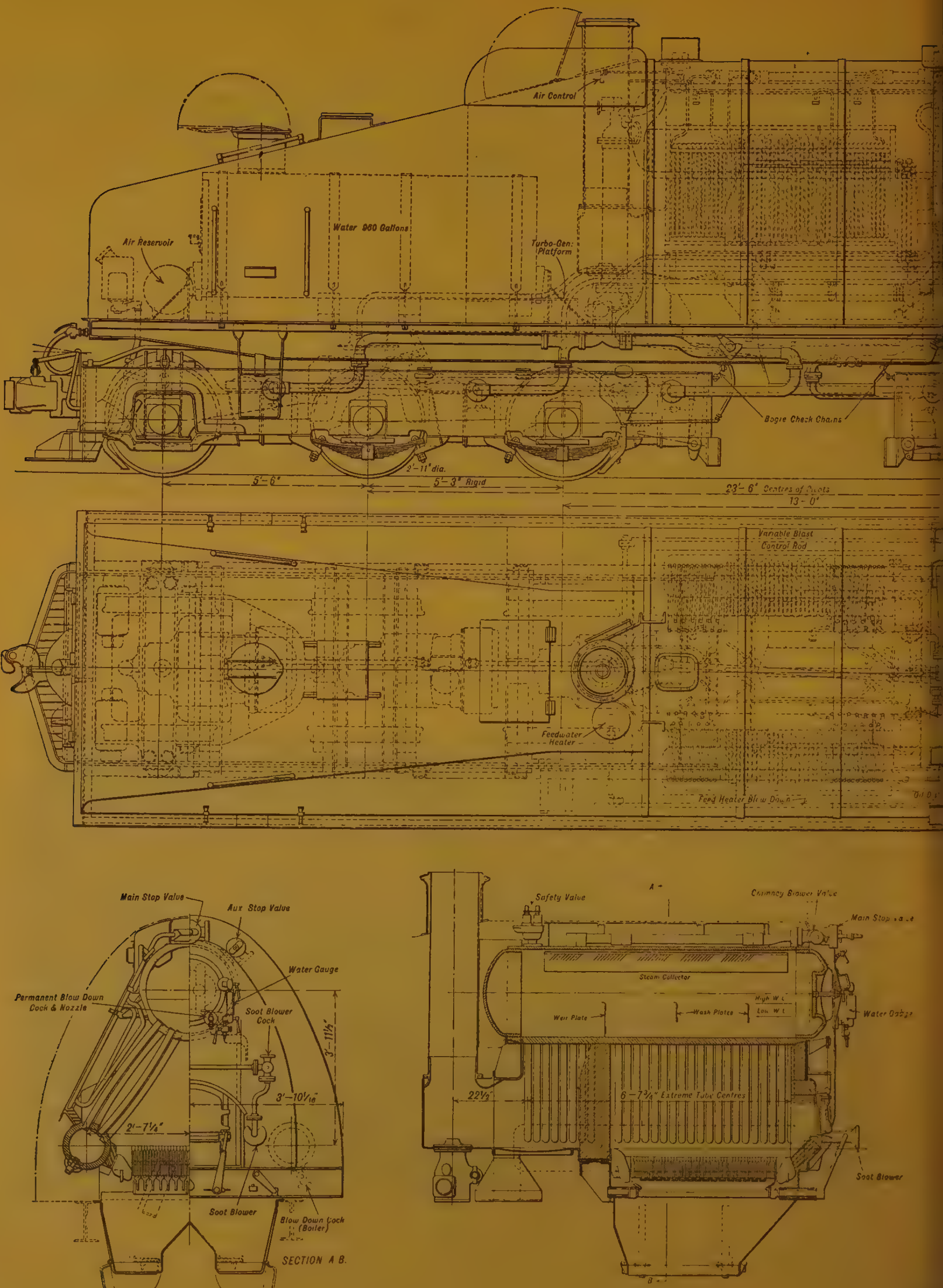
In figure 2 there are reproduced general arrangement drawings of the locomotive and the boiler fitted in it. The latter is of the « Woolnough » water-tube type and, compared with the ordinary smoke tube locomotive boiler, is very short in length. Beyond it at the leading end of the locomotive there is space within the outer casing to accommodate a large water tank, and further forward still there is an air reservoir for the Westinghouse brakes, and parts of the sanding gear. The arrangement behind the cab is more normal. There is a coal bunker and another water tank. So much for the general features of the body. The boiler supplies steam to six high-speed double-acting compound engines mounted in the bogies beneath the frame, each driving one axle through gearing. The bogies have a three-axle arrangement and the leading axle of the front bogie and trailing axle of the rear bogie are carried in bissel trucks, so that curves of small radius may be negotiated safely. Some general particulars and dimensions are given in the following table :

Particulars of Sentinel six-axle locomotive.

Gauge	1 m. (1ft. 3 3/8 in.).
Length over couplings	About 43ft.
Length between bogie centres	23ft. 6in.
Length between bogie fixed axles	5ft. 3in.
Height to top of chimney	12ft. 6in.
Width overall	About 8ft. 3in.
Number of engines	Six.
Tractive effort	17 500 lb.
Radius of smallest curve	80 m. (4 chains).
Water tank capacity	1 200 gallons.
Coal bunker capacity	3 tons.

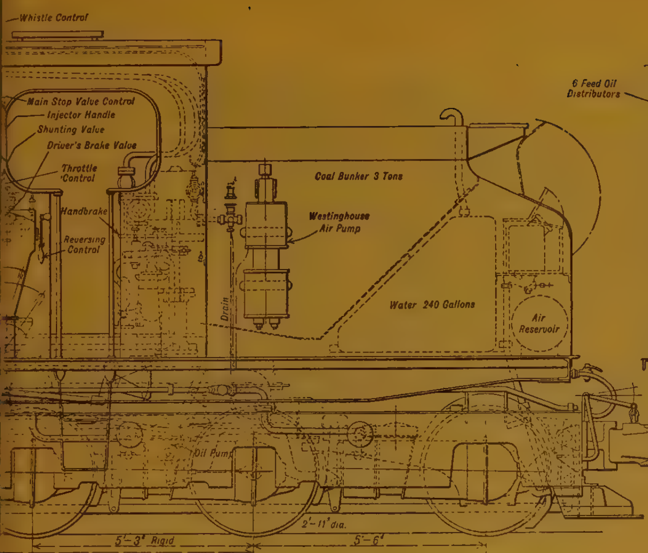
The boiler.

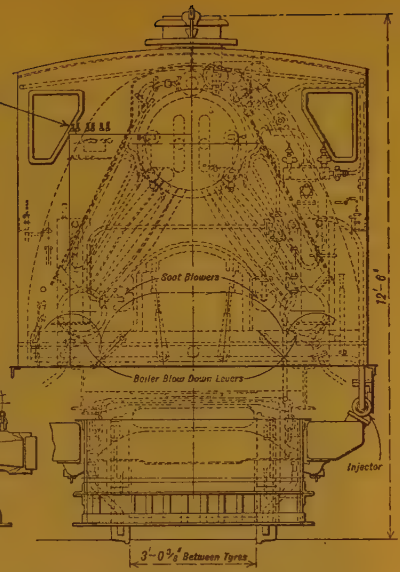
We gave a short description of a « Woolnough » boiler fitted in a 200-H.P. steam rail coach on November 28th, 1930. Since that date several minor improvements have been made, although the general features of the design remain the same. The arrangement is now such that, except for the boiler drums and a few other of the larger pieces, a boiler for any required duty can be built up from standard parts. Drawings of the boiler installed in the Colombian locomotives are reproduced in figure 2. The « Woolnough » boiler has three drums. The two lower drums are disposed one on each side of the grate and are connected by banks of tubes slightly curved and inclined at a steep angle to a steam drum centrally placed above the grate. At a point about two-thirds along the length of the boiler a fire-brick wall 9 inches thick closes the space between the three drums and the banks of tubes and so forces the products of combustion to travel outwards through the tube banks. In the space between the tube banks and the boiler casing the superheater tubes are so situated that, while they can freely absorb heat from the gases, they also protect the boiler casing from the heat. From this space the gases, having circled around the ends of the fire-brick wall, travel back through the tube banks to the smoke-



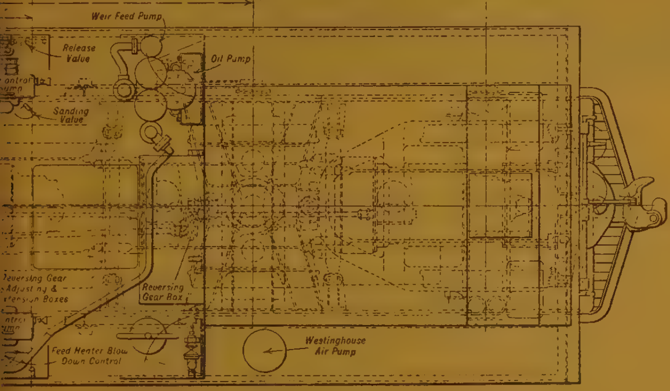
Air Control
Water 960 Gallons
Air Reservoir
Turbo-Gen: Platform
Bogie Check Chains
2'-11" dia.
5'-6"
5'-3" Rigid
23'-6" Centres of Pivots
13'-0"
Variable Blast Control Rod
Feedwater Heater
Feed Heater Blow Down
Main Stop Valve
Aux Stop Valve
Water Gauge
Permanent Blow Down Cock & Nozzle
Soot Blower Cock
3'-11½"
3'-10 1/16"
2'-7¼"
Soot Blower
Blow Down Cock (Boiler)
SECTION A B.
Safety Valve
Steam Collector
Weir Plate
Wash Plates
22½"
6'-7¾" Extreme Tube Centres
Soot Blower

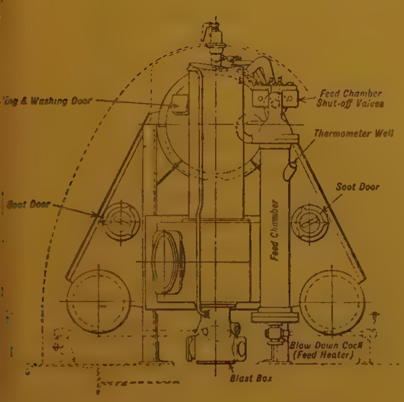
Fig.



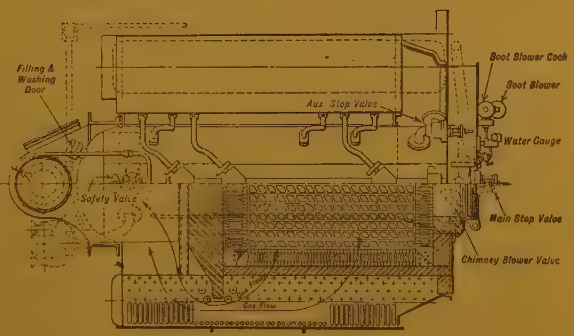


END VIEW LOOKING FORWARD.





VIEW LOOKING ON CHIMNEY END.



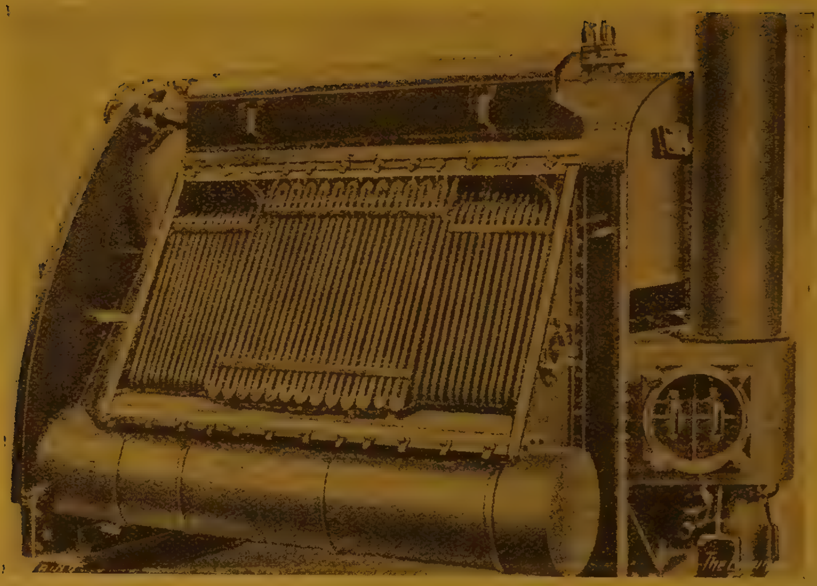


Fig. 3. — The Woolnough boiler.

box, from which they are ejected up the chimney by the exhaust blast of the steam blower. The air for the combustion of the fuel is drawn in through balanced louvres in the partition between the smoke-box and the front water tank and passes outside the boiler casing and within the external casing of the whole around the boiler to the ashpan. By this means the boiler casing is kept cool and the combustion air preheated, use being thus made of heat which would otherwise be lost by radiation. The balanced air louvres are arranged to open proportionately to the amount of vacuum induced by the blast and to close automatically when steam is shut off.

The grates are made in two similar parts, each of which is mounted on a longitudinally arranged trunnion. Each half is independently operable from the foot-plate and the arrangement allows the fire to be easily cleaned or dropped into the ashpan. Some general particulars of the boiler are given in the following table :

The « Woolnough » boiler.

Heating surface :	
Generating tubes	344 sq. ft.
Superheater	145 sq. ft.
Total	489 sq. ft.
Grate area	16.6 sq. ft.
Working pressure	550 lb. per sq. in.
Length of top drum	About 9ft.
Length between extreme tube centres	6ft. 7 3/4in.
Height, centres of drums	3ft. 11 1/2in.
Diameter of steam drum, external	2ft. 3in.
Diameter of water drums, external	1ft. 2in.

In connection with this boiler, which is also illustrated by the tone engraving figure 3, we asked particulars regarding the effects of the use of hard feed water and whether blowing down was a frequent necessity. The greater part of the solids, it appears, is precipitated in the feed heater, which is of the Gresham and Craven pattern, and consists of two check valves for the injector and feed pump respectively, combined with delivery cones. Through these cones the feed water passes into a chamber connected with the steam space of the boiler and the force of the discharge is such as to mix the steam and water so intimately that the latter is heated up almost to the temperature of the former. Before entering the boiler proper the feed water is allowed to stand for a short while in a settling chamber, in which a large proportion of the solids is precipitated out. A blowdown cock is, of course, fitted to this chamber. All the solids, however, are not removed. The water enters the top drum of the boiler at the end remote from the furnace and it is believed that a very definite circulation exists, the water travelling downwards from the back of the steam drum through the tubes around the smoke-box, where the flue gases are coolest, and returning upwards to the top drum through the tubes surrounding the grate. Certainly the rapid steaming qualities of the boiler suggest that some such active circulation exists. As a result of this circulation, which incidentally is encouraged by the provision of a weir plate in the top drum, those solids which have not already been deposited in the feed heater settling chamber are thrown out in the water drums at the end remote from the fire. It is recommended that the boiler should be blown down twice a day. If water containing nitrates must be used it is considered essential that the water should be treated either before the tanks are filled or alternatively actually in the tanks. Where less corrosive waters are concerned treatment is considered advantageous but not essential.

It is obvious that when a boiler is likely to be fired with several grades of fuel, some good and some bad, the amount of draught and combustion air required will vary. The amount of combustion air drawn in is automatically regulated by the inlet louvres according to the vacuum induced by the blast, while the size of the nozzle of the latter is variable and can be altered from within the cab. Steam soot blowers controlled from the cab are also provided for keeping the exterior of the boiler tubes clean.

Equipment of main frame.

The equipment mounted on the main frame, besides the boiler, can be clearly seen in the line engraving reproduced in figure 2. Forward of the boiler there is a water tank with a capacity of 960 gallons, an air reservoir for the Westinghouse brakes and the sanding gear equipment for the leading bogie. Between the boiler and the tank and to one side there is a small platform on which a small turbo-generator is to be mounted for lighting purposes. A Weir feed pump of more or less standard design, modified to suit the conditions, is situated in the right-hand corner of the back of the cab. Behind the cab there is a coal storage bunker with a capacity of 3 tons and a second water tank holding 240 gallons and connected to the larger one at the forward end of the locomotive by a balance pipe. The amount of water in the tanks is indicated by a gauge glass at the back of the cab. Behind the tank there is another air reservoir for the Westinghouse equipment and the sanding gear for the rear bogie. The Westinghouse air pump is mounted outside the tender on the left-hand side.

The bogies.

But short reference need be made to the bogies. They are of straightforward

design with provision for allowing the axle loads to be varied. They are pivoted to the main frame above the central axles, and the outermost axle of each is mounted in a bissel truck so that the locomotive shall be able to negotiate freely curves of not more than 4 chains radius. Springs are fitted to the bissel trucks to regulate the side movement. All the axle-boxes are identical, except for the spring links, and they are of the roller bearing type lubricated by grease. Each axle, as we have mentioned before, is separately driven through gearing by a compound expansion totally enclosed steam engine mounted in the bogie. These engines can be seen clearly in the engraving, figure 4. Separate flexible steam pipes, also visible in the engraving, connect each engine with the main throttle valve and the exhaust blast. Automatic couplings are fitted at the outer ends of the bogies. On that locomotive which has undergone trials in Belgium buffers and draw-bar gear was fitted temporarily to suit the practice of the railway concerned.

The engines.

It is difficult not to become lyrical about the design and construction of the engines. At Shrewsbury we were shown the dismembered parts of an engine similar to those fitted to the Colombia locomotives. The workmanship is of a kind that delights the heart of any engineer. The line engraving figure 6 shows sections through a complete engine. In prosaic detail each engine is a double-acting totally enclosed compound with cylinders 4 1/4-in. and 7 1/4-in. diameter by 6-in. stroke. It drives a symmetrically designed crank shaft running in roller bearings and carrying at its centre a hardened and ground pinion which meshes with a gear wheel on the centre of the axle. The ratio is 2.74 : 1. Each engine is mounted horizontally in the bogie frame with its crank axle

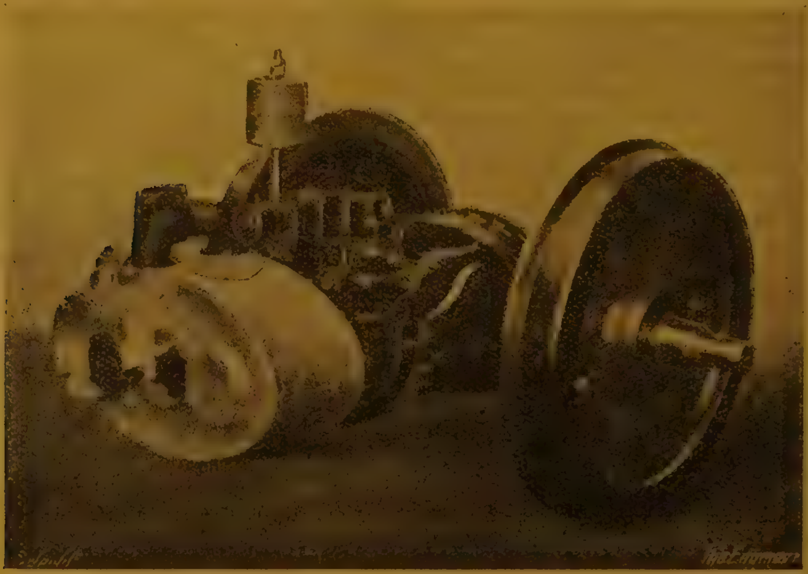


Fig. 4. — One of the six compound engines, open.

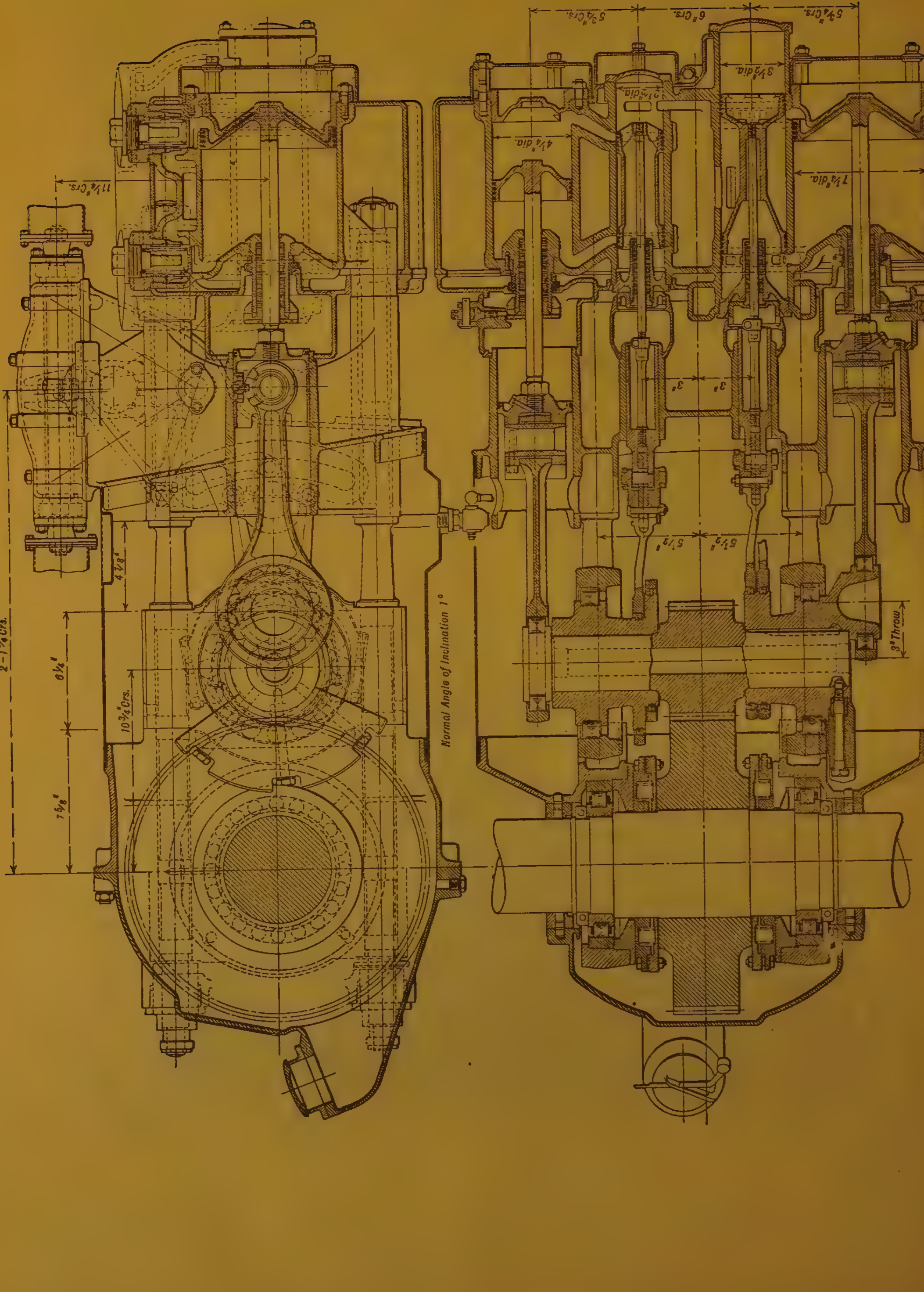
across the frame. It is supported at one end by the axle and at the other by a suspension link. This link, which is shown in the drawing figure 11 is attached to the engine by a ball joint

Fig. 5. — One of the bogies.

at a point slightly further from the axle than the centre of gravity of the engine and to the bogie frame above by a silent bloc rubber mounting. In this way it will be seen that, while the engine is soundly supported, it is yet allowed to follow freely the movements of the axle. By far the greater part of the weight is carried by the link, the remainder by the axle.

Examination of the line engraving figure 6, will show that the parts of the engine are built up upon and held together by four stanchions. The whole of the motion gear and crank shaft assembly is enclosed in the crank case, which is partly filled with oil. All the moving parts are therefore thoroughly lubricated by splash. The crank shaft, which is carried in roller bearings, and to which the connecting-rods and eccentrics are attached by roller bearings, is a built-up structure. The pinion at its centre is cut and ground to form out of the solid and forms part of a shaft to which two separate crank shaft pieces are keyed. Each of these latter comprises a main bearing, crank pin, and eccentrics, and the two are identical. They are hardened and ground at the bearings. The pistons are turned out of the solid, and the crossheads are of cast steel. The workmanship reaches its highest point perhaps in the making of the eccentrics. They are of very light and narrow section, in spite of the fact that they must be hardened and ground to take the rollers of the bearings. We inquired as to the number which had to be rejected owing to distortion in the hardening process and were surprised to find the figure very low. Reversal and cut-off are controlled by a Stephenson link motion. The curved link and block are particularly good examples of the work of skilled hands. We tried the motion of the block between our fingers and could detect no difference of « feel » as it was slid from one end of the link to the other. Piston valves are used; the drawings and tone engravings will speak for themselves as to the neatness and compactness of the design.

A matter that we found particularly interesting was the provision made to overcome the possibilities inherent in water finding its way into cylinders of which the clearance volume is very small. At each end of each cylinder there is a valve consisting of a small piston loaded on the top by a light spring. Since the steam is allowed to act on both sides of the piston, this light spring is sufficient under normal conditions to hold the piston down. Should there be water in the cylinder, however, it is forced upwards as the main piston



"THE ENGINEER"

approaches the end of the cylinder and the water is allowed to escape through a side passage to the steam chest on the low-pressure receiver according to the cylinder concerned.

The Stephenson link motion is operated by linkage from a screw and nut mechanism contained in a box mounted above the engine. Steam is brought to each engine from the main throttle valve through an individual pipe provided at suitable points with ball joints to provide the necessary flexibility. Isolating valves are placed in these pipes in positions easily accessible from the track. Thus, should it be undesirable to admit steam to any one of the engines, this valve can be closed and the locomotive propelled by the remainder. In the unlikely event of the complete failure of an engine it can be disconnected from the axle by slacking back the large nuts on the crank case end of the engine stanchions. By this means the pinion on the engine crank shaft is taken out of mesh with the gear wheel on the axle.

Controls.

There are six separate engines under the driver's charge, and it is, of course, necessary that they should be all controlled together so that the multiplicity of driving units shall not make the driver's task too complicated. As far as most of the controls are concerned the matter is one of no great difficulty. Equality of cut-off, for instance, in the six engines is a matter for accurate setting in the works before the locomotive is sent away. It will be remembered that the Stephenson links on the engines are operated by a screw and nut mechanism. The six screws are all interconnected by rods with flexible joints and are carefully adjusted in the works to give the desired equal cut-off. But in the case of the throttle valve the matter is less simple. If, for instance, this valve was arranged to admit steam to a main chest from which all six engines drew steam, the operation of the locomotive would be unsatisfactory. For should one axle slip on the rails the engine driving it would take all the steam and starve the others. Individual control is, therefore, necessary, but it is obvious that undesirable complication would exist if there was a separate throttle valve for each engine. The design of throttle valve adopted is shown by the drawing figure 7. It is of the poppet type and closes on to a conical seat. Beneath this seat there is a piston-

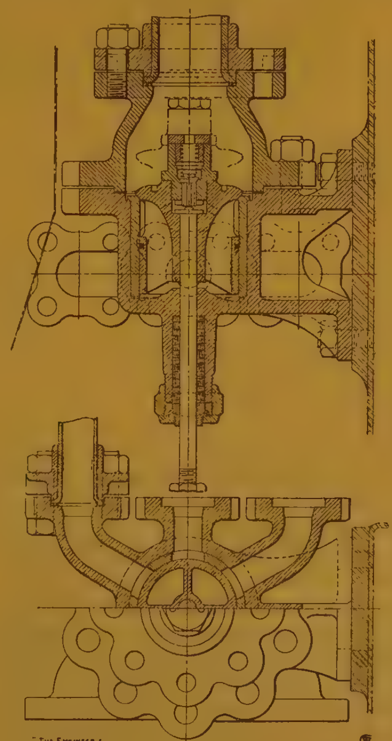


Fig. 7. — Throttle valve.

like extension which covers six ports, each of which admits steam to the pipe line to one engine. The main valve lifs about one-eighth of an inch before the piston-like extension begins to uncover

the ports. It will be seen that with this arrangement, if one axle starts to slip, a throttling action will take place in the port leading to the engine concerned, so that the remaining engines will still draw steam at an adequate pressure.

For starting purposes live steam is automatically admitted to the low-pressure cylinder of each engine. But in order that it may not be necessary to design the low-pressure side heavy enough to carry the stresses which would be caused by allowing the full pressure to act on the low-pressure piston, special measures are taken to reduce the pressure automatically before the steam is

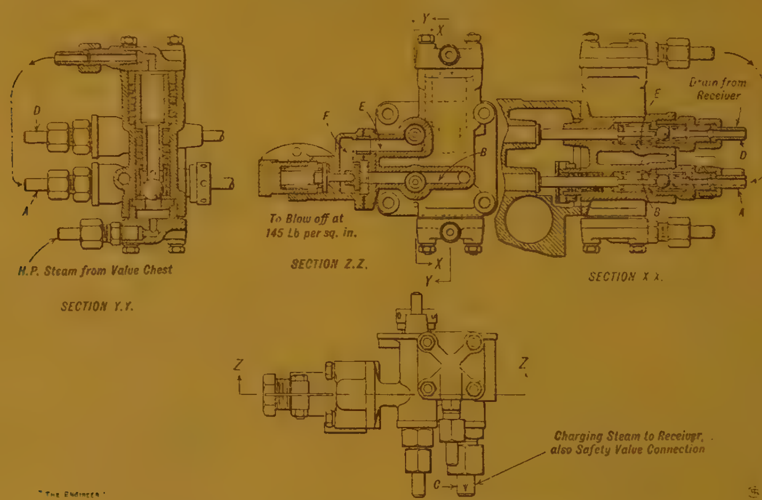


Fig. 8. — Charging, drain, and safety valve.

admitted to the low-pressure cylinder. This object is effected by the charging, drain, and safety valve, which, as its name implies, has two other duties to perform as well. The device is shown by the engraving, figure 8, and is attached to each engine above the crossheads.

Examining the section XX, it will be seen that two ball valves can be lifted off their seats by two rods projecting through the casing. The ends of the rods bear against plungers which are operated from the screw and nut mechanism controlling the Stephenson link motion. When starting up from cold the link motion is put in mid gear and both the plungers are forced outwards so that the rods lift the ball valves from their seats. Steam from the main valve chest, to which it has been admitted by slightly opening the throttle, now enters the charging, drain, and safety valve by the branch at the bottom. It passes upwards through a reducing valve, the working of which will be explained later, and emerges from the branch at the top. Thence, through an external pipe, the steam is led back into branch A — see section XX — and passing through the ball valve, which is held open by the rod, finds its way *via* cross passages B — section ZZ — to the branch C, which leads it to the top of the low-pressure receiver. It returns to the charging valve through branch D and, finding its way past the ball valve in this passage, finally goes to exhaust through the cross passage E and the exhaust passage F. In

this way the engine is warmed up and drained.

When it is desired to start the locomotive the Stephenson link motion is moved to the full forward or reverse position. In this position of the link motion only the lower of the two ball valves is held open. Then steam at high pressure — for the throttle valve will be more fully opened — can find its way as before through the charging valve to the low-pressure receiver, but since the upper ball valve is on its seating, can go no further. It is under this condition that the reducing valve begins to function. The steam pressure in the low-pressure receiver must not exceed 145 lb. per square inch, or the safety valve, to be seen at one end of cross passage B — section ZZ — will lift and allow the steam to escape to exhaust. But the steam at its first entry to the charging valve may be at a pressure of 500-550 lb.

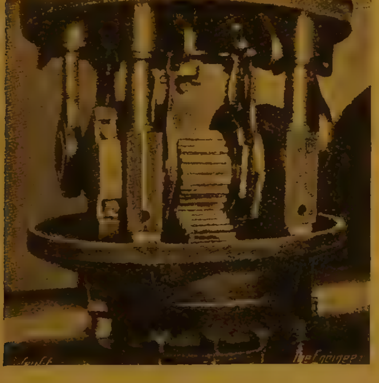


Fig. 9. — Crankshaft and gearing.

per square inch. This high pressure acts from beneath on the ball at the bottom of the reducing valve — see section XX — and tends to lift it off its seat together with the « piston » above. Observation, however. will show that the area upon which the steam above can act is much greater than that below. If, therefore, the pressure beyond the valve exceeds a certain limit — actually about 140 lb. per square inch — the « piston » is forced down and the ball valve is pushed on to its seating, preventing the admission of steam. Actually, of course, the valve maintains the ratio between the steam pressures on its two sides. If that on the high-pressure side is less than 500-550 lb. per square inch the valve will close before the pressure on the other side reaches 140 lb. per square inch.

When the locomotive is running normally with the cut-off at some earlier position, neither of the two rods is holding a ball valve off its seat, and consequently no steam finds its way *viâ* the charging valve to the low-pressure receiver.

Many of the handles and levers in the cab are similar controls to those found in any locomotive and need not be referred to. As will be seen from the photograph reproduced in figure 10, there is a control pillar on each side of the cab. The lever running in a slot controls the throttle valve. Its first motion opens a pilot valve which admits steam to the space below the main valve and puts it in balance. Behind the throttle lever and in a convenient position for the driver there is the handle controlling the reversing gear. A scale and pointer alongside the throttle lever indicates the direction of travel and the setting of the cut-off. When starting from cold or after a lengthy stop the reversing gear is placed in the mid-position (the brakes being on) and the throttle partly opened. As has already been noticed, this action allows the steam to blow through the engines for warming up. The throttle lever is so interconnected with the reversing gear that in mid-gear it can only be partially opened. When the engines have been warmed the reversing gear handle is turned until full forward or reverse position is obtained and the throttle opened. The charging valve then admits steam directly to the

Fig. 10. — Interior of cab.

low-pressure cylinder. On notching up the cut-off the charging valve is put out of action automatically and the engines run compound. The locomotive cannot be run linked up beyond 50 % cut-off with the throttle wide open, as an interlock partially closes the throttle beyond this point.

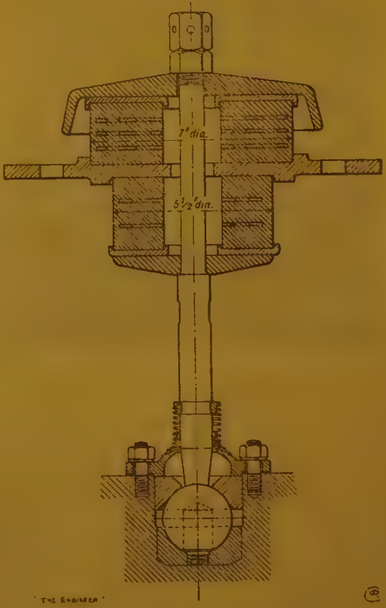


Fig. 11. — Engine suspension link.

The flexible connecting-rods of the screw and nut mechanism for the Stephenson link motions have already been mentioned. These flexible shafts are linked under the footplate to a gear-box which is operated by chains from the handles on the control columns. Beside the control columns on each side there can be seen in the engraving the hand levers controlling the Westinghouse brakes. The levers for the rocking grates and the hand wheels for the soot blowers are also to be seen on each side of the firedoor. The big valve on the top of the boiler is the main stop valve. The other valves control the admission of

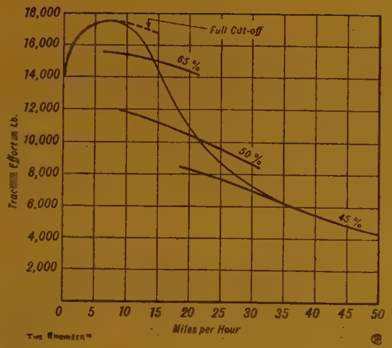


Fig. 12. — Tractive effort at various speeds.

steam to the sanding gear, Westinghouse pump, injector, feed pump, etc.

Lubrication.

As we have already mentioned, the working parts of the engines are lubricated by splash from the oil in the crank cases, while the roller bearing journals of the axles, being grease lubricated, need only very occasional attention. For cylinder lubrication a mechanical lubricator is driven off the right intermediate wheel journal end of the trailing bogie and forces oil under pressure into a six-feed distributor mounted in the cab. Thence individual pipes lead the oil to the six engines, the supply of oil to each being separately regulated at the distributor.

Maintenance, accessibility, etc.

These Sentinel locomotives have a number of interesting advantages. Where a number of the vehicles are in service and boiler inspection can be carried out on a routine basis, a complete boiler can be expeditiously removed from a locomotive and replaced by another. Similarly, for the overhaul of the engines it is a matter of no great difficulty, or expenditure of time, to remove an engine and axle complete and substitute another. On the running side the low axle weights, combined with the fact that the wheels and axles are in perfect running balance, is kind to the road and should be reflected in reduced road maintenance, while the uniform torque gives a high factor of adhesion and makes it possible to start and to haul very heavy loads. The « Woolnough » boiler, it is claimed, is capable of raising steam in less than half the time which would be required for an ordinary locomotive boiler for the same power; while with a steam consumption by the compound engines of 13 lb. per B.H.P. hour it is believed that a 50 % saving in fuel burnt will be obtainable.

One of these locomotives, as we mentioned at the beginning of this article, has been undergoing trials in Belgium. The metre-gauge line on which it was used is not conspicuous among railways for the excellence of the laying of the track; there are many curves of small radius, steep gradients, road crossings, and the like, and very many speed restrictions are in force. Consequently the tests could not be exhaustive. Sufficient was practicable, however, to demonstrate that the locomotive was fully satisfactory, and to show that its actual performance agreed closely with that estimated and shown in the accompanying diagram. The locomotive was designed to haul a passenger train weighing 200 tons gross over a ruling gradient of 2 % and its gear ratio was designed for this gradient. The corresponding load for the 3 1/2 % gradients on the Belgian line is estimated to be 123 gross tons of passenger train or 100 tons of goods train. The locomotive hauled a goods train weighing 114 tons made up of short wheel base 10-ton wagons over the 3 1/2 % gradient. The trials were witnessed by Mr. Gresley and Mr. Stanier and technical representatives of the other railways of this country and abroad.

[621. 132.3 (.42) & 621. 132.6 (.42)]

New three-cylinder 2-6-4 tank locomotives and 4-6-0 express locomotives for the London Midland and Scottish Railway.

(From *The Railway Engineer.*)

At the present time two interesting classes of three-cylinder locomotives are under construction for the London Midland and Scottish Railway to the designs of Mr. W. A. Stanier, Chief Mechanical Engineer, namely, 4-6-0 modified 5XP class engines for general express service, and 2-6-4 passenger tank engines for fast suburban work. Both engines have many standard parts in common.

Fig. 1.

The new tank engines, which are now being built at the company's works at Derby to the number of 37, have the same wheel arrangement as that of the existing standard 2-6-4 two-cylinder class, of which 125 are in service, the numbers ranging from 2300 to 2424 inclusive. The new series, however, provides a greater output of power, and the three-cylinder arrangement has been

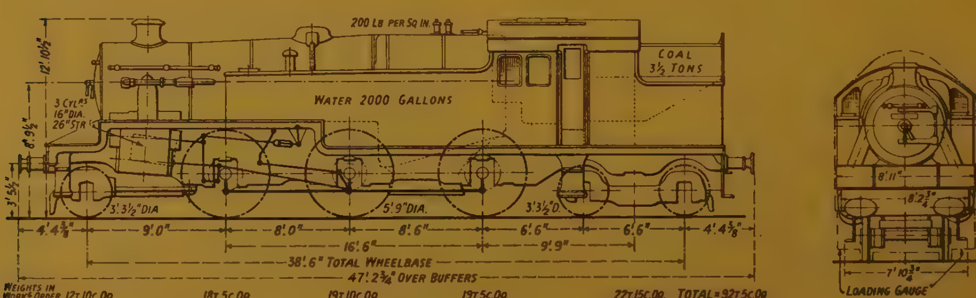


Fig. 2. — Diagrams of front end and side elevation of 2-6-4 tank locomotive.

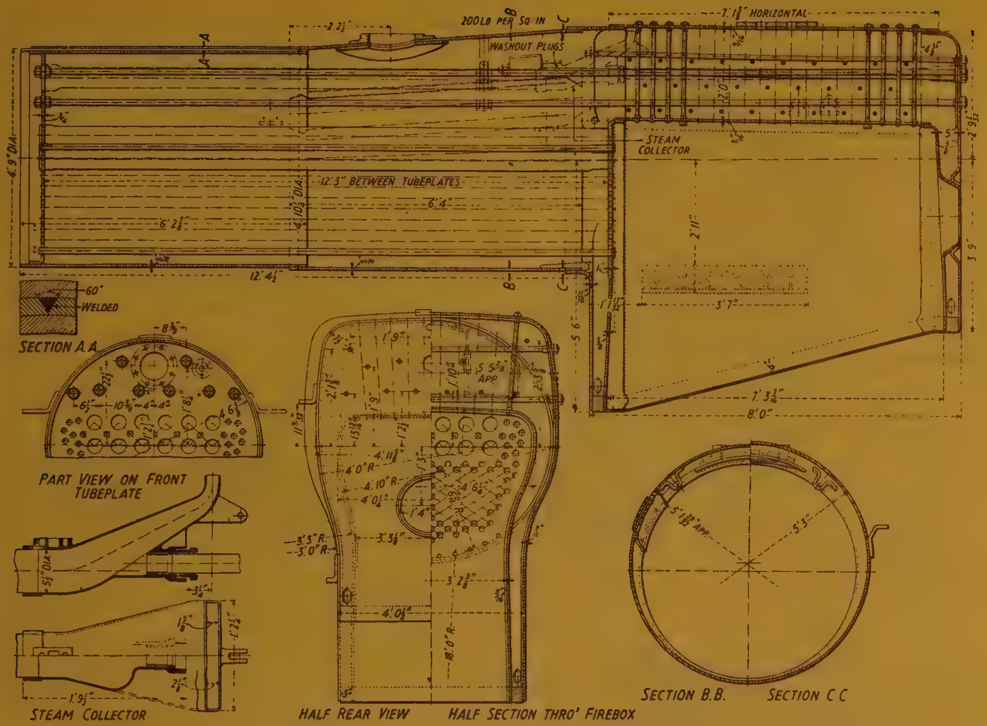


Fig. 3. — Boiler and firebox details.

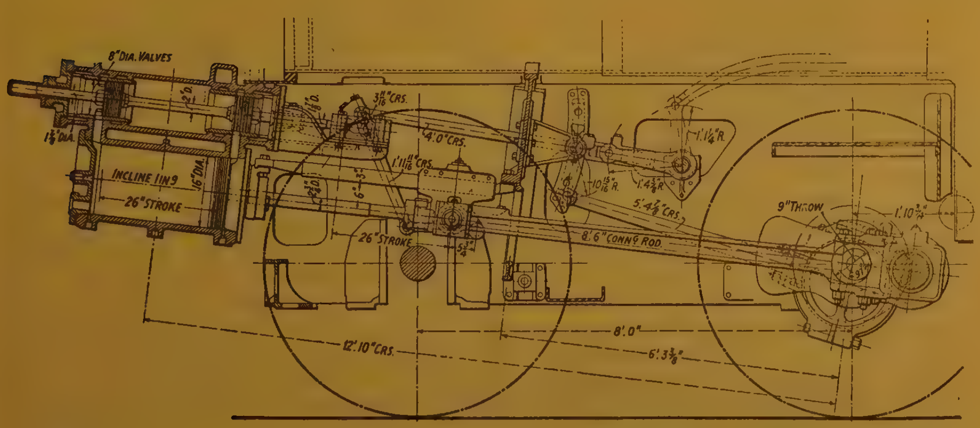


Fig. 4. — Arrangement of inside cylinder, piston, valve, and Walschaerts valve motion.

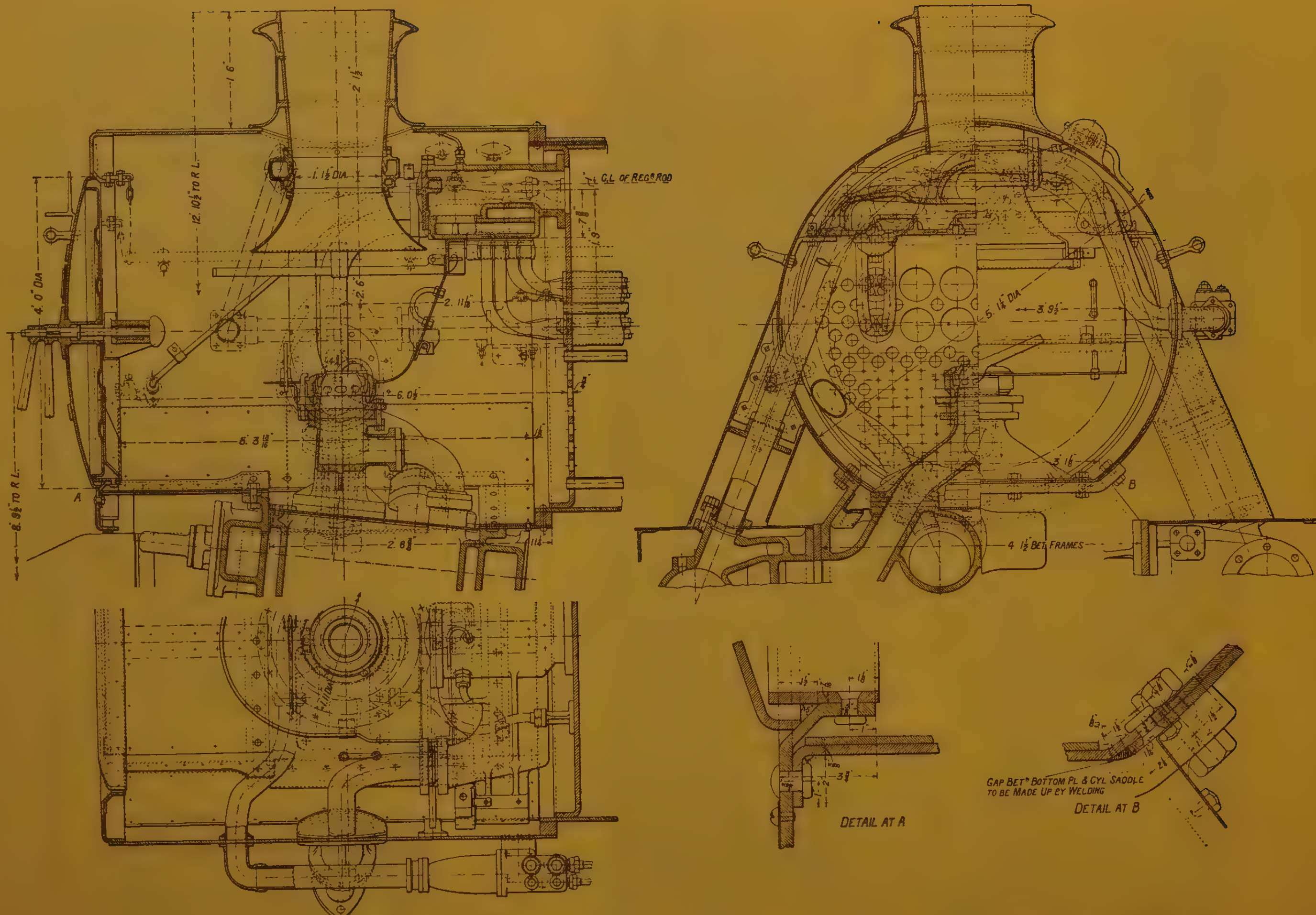


Fig. 5. — Details of the front end of the new L. M. S. R. three-cylinder tank locomotive. The careful design to reduce wire-drawing and back-pressure will be noted.

adopted as a means of ensuring high acceleration for working fast suburban traffic. Some of the engines will be used on the Tilbury and Southend section, where these qualities will be especially useful.

The three cylinders are inclined and drive the second pair of coupled wheels; double slide bars are used for the outside cylinders, and a single slide bar for the inside motion, the latter being necessary in order to accommodate the Walschaerts gear and to clear the leading straight axle. The piston valve steam chests are placed above the cylinders, slightly offset from the centre lines. The coupling and connecting rods and motion details are, in accordance with the latest practice, made of high-tensile manganese-molybdenum steel. The connecting rods are of fluted section, and that of the coupling rods rectangular. The piston valves, cylinders and piston rod packings are provided with mechanical lubrication, each piston valve head being fitted with a steam atomiser, the control valve for which is mounted under a cover near the top of the smokebox on the left-hand side. The valve spindle bushes are also mechanically lubricated. The mechanical lubricators are of the railway company's standard type.

The wheel centres take the form of steel castings with the wheel rim of triangular section, and the tyre fixing is of the Gibson retaining ring type. The balance weights for the coupled wheels are built up of steel plates on both sides of the spokes and riveted, the requisite weight being provided by filling in between the plates with lead. For the coupled wheels cast steel axle-boxes are used, having pressed-in brasses with a white-metal crown and oil grooves on both side of the crown to ensure a thorough distribution of oil to the journal. The axlebox underkeep carries an efficient oil pad. The leading and trailing axleboxes are arranged so that the oil pads can be examined by sliding out the underkeep while the axlebox is in position (see illustrations, figs. 6 to 8). This arrangement cannot, however, be provided on the middle coupled axlebox on account of the crank axle and eccentric. Each of the axle-boxes is provided with a dust shield carried on the inside face of the box. A separate mechanical

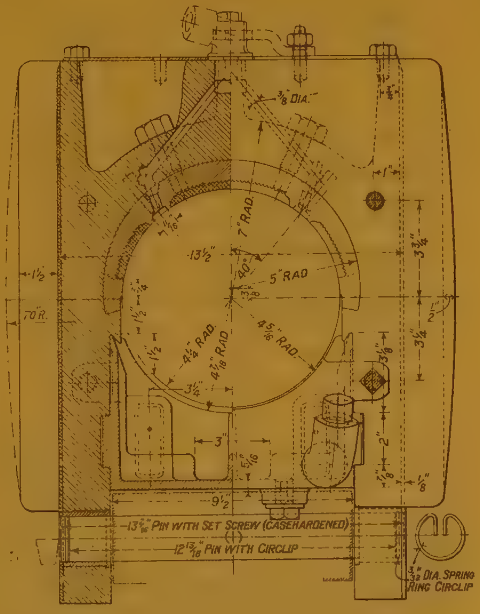


Fig. 6. — Half section through axlebox.

lubricator supplies the coupled axleboxes, each with an independent oil feed to the crown of the box, and a standard back pressure valve and flexible oil pipe connection.

All the laminated bearing springs for the engine are made of silico-manganese steel, the plates being of ribbed section and having the cotter type fixing in the buckle. The spring links are of the screwed adjustable type.

The two-wheeled leading truck with its anchor pin is attached to a cross stretcher between the main frames at a distance of 6 ft. 7 3/4 in. behind the

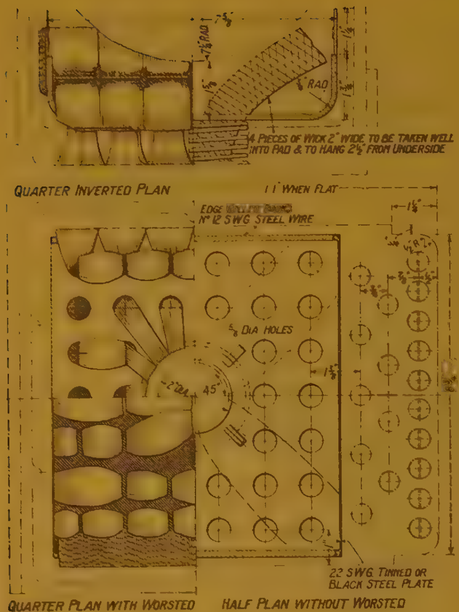


Fig. 7. — Details of oil pad.

Fig. 8. — Axlebox with sliding underkeep and dust protector.

truck wheel centre. The weight on the truck is taken through side bolsters, and the bogie side check spring gear has been carefully arranged to ensure smooth riding. The four-wheeled bogie at the other end is of the company's standard type, the weight being taken through side bolsters, while the bogie side check spring gear is very flexible and ensures smooth riding.

The boiler barrel is tapered and has an outside diameter of 4 ft. 9 in. at the front end, increasing to 5 ft. 3 in. where it joins the firebox. The latter is of the Belpaire type and has mounted upon it two Ross pattern pop safety valves 2 1/2 inches diameter, which blow off at the boiler pressure of 200 lb. per sq. inch. A standard type of sliding fire door is provided and a screen is used to prevent glare from the fire. The boiler is fed by a Davies & Metcalfe exhaust steam injector with 9-mm. cones fitted on the fireman's, *i.e.* the right-hand, side, and a Gresham & Craven live steam injector with 10-mm. cones mounted on the left-hand side. Other boiler mountings, such as a water gauge, frames and protectors, etc., are of the railway company's standard type. The regulator is in the smokebox.

The controls for the steam supply are conveniently placed on a steam manifold having a main shut-off valve located on the top of the firebox door plate in the cab. This carries the necessary valves for the ejector and steam brake, injectors, carriage warming, whistle, pressure gauge and sight feed lubricator to the regulator. The boiler feed water is supplied through top feed valves fitted on the second boiler ring and having water distributing trays. The cab is completely enclosed and, as we are able to testify from inspection at the Derby works, very conveniently arranged, roomy, with good ventilation, and a clear lookout in both directions. The width over the

cab and side tanks is 8 ft. 10 1/2 in. The drive is on the left-hand side, and all controls are arranged for convenient handling. Tip-up seats are fitted on each side of the cab, and there are also two sliding windows on each side with hinged windows on the front and back plates of the cab. A new feature is that the coal bunker is narrowed at the top so that a clear lookout is provided when the engine is running bunker first.

The steam brake is fitted to the coupled wheels of the engine, and is controlled by the driver's vacuum brake valve. A vacuum pump is carried on the inside of the motion plate and is driven from a connection from the inside cross-head. When the engine is standing, the small ejector maintains the vacuum on the engine and train. The fitting seen in the photograph at about the centre line of the boiler and alongside the smokebox comprises the ejector for the vacuum brake apparatus. A hand brake is also used. The sanding arrangements are of the mechanical trickle type, the sand being delivered in front of the leading wheels and at the front and back of the middle (driving) pair of coupled wheels. In addition to this a water de-sanding apparatus is provided which automatically comes into action, so that after the engine has used the sand in the fore or reverse direction, as the case may be, the rails are cleaned with hot water to prevent interference with the track circuits.

The following are the main particulars :

Cylinders (3) diameter . .	16 inches.
» stroke . . .	26 inches.
Wheels, coupled	5 ft. 9 in.
Wheelbase, coupled . . .	16 ft. 6 in.
» total engine .	38 ft. 6 in.
Boiler working pressure .	200 lb. per sq. inch.
Heating surface, tubes . .	1 011 sq. ft.
» firebox .	137 sq. ft.
Total	1 148 sq. ft.
Superheater	160 sq. ft.
Combined total.	1 308 sq. ft.
Grate area	25 sq. ft.
Weight of engine in working order	92 tons 5 cwt.
Water capacity of tank .	2 000 gallons.
Coal capacity of bunker .	3 1/2 tons.

The engine exerts a tractive effort, at 85 % of the boiler pressure, of 24 600 lb. The series will be numbered 2500 to 2536 inclusive.

Three-cylinder 4-6-0 type locomotives.

The new three-cylinder 4-6-0 passenger locomotives, of which 113 are being built for general express passenger service on the L.M.S.R. main lines, are similar in their main features to the previous 5X class except that the boilers are tapered and the cab and tender of modified pattern. The orders have been allocated as follows :

No. of engines.	Engine Nos. inclusive.	Place of construction.
53	5552 to 5556 5607 to 5654	Crewe locomotive works.
50	5557 to 5606	North British Locomotive Co. Ltd., Glasgow.
10	5655 to 5664	Derby locomotive works.

The first of these engines, No. 5552, was completed quite recently at Crewe works, and, after running its trial trips, was despatched to Euston and exhibited there, together with some of the latest passenger rolling stock on April 23. The accompanying reproductions are from photographs taken with Mr. Stanier's permission by our own photographer at the Crewe works on the day the engine was steamed. The engines, which belong to the 5XP class, have dimensions as follow :

Cylinders (3) diameter	17 inches.
» stroke	26 inches.
Wheels, coupled, diameter	6 ft. 9 in.
Wheelbase, coupled	15 ft. 4 in.
» total, engine	27 ft. 5 1/2 in.
» engine and tender (with 4 000-gallon tender) . . .	54 ft. 3 1/4 in.

Boiler, height of centre from rail	8 ft. 11 in.
» barrel, length	13 ft. 10 in.
» diameter outside, smokebox end	5 ft. 0 in.
» » » firebox end	5 ft. 8 3/4 in.
Superheater element tubes:	
(14) 1 3/8 in. diam. outside × 11 S.W.G.	
(14) large tubes 5 1/8 in. diam. outside × 7 S.W.G.	
(16) small tubes 2 in. diam. outside × 11 S.W.G.	
Heating surface, tubes	1 462.5 sq. ft.
» » firebox	162.4 sq. ft.
Total	1 624.9 sq. ft.
superheater	227.5 sq. ft.
Combined total	1.852.4 sq. ft.
Grate area	29.5 sq. ft.
Boiler working pressure	225 lb. per sq. in.
Tractive effort at 85 % boiler pressure	26 610 lb.
Weight of engine in working order	80 tons 15 cwt.
» tender in working order (4 000 gall.)	54 tons 2 cwt.
Weight of engine and tender in working order	134 tons 17 cwt.

Fig 9

Many of the component parts of these locomotives are similar to those fitted to the new L.M.S.R. 2-6-4 type tank engines already described, this applying in particular to the design of the wheel centres, axleboxes, lubricating and sanding systems, springs, superheater, front end, and brake system. Similarly the

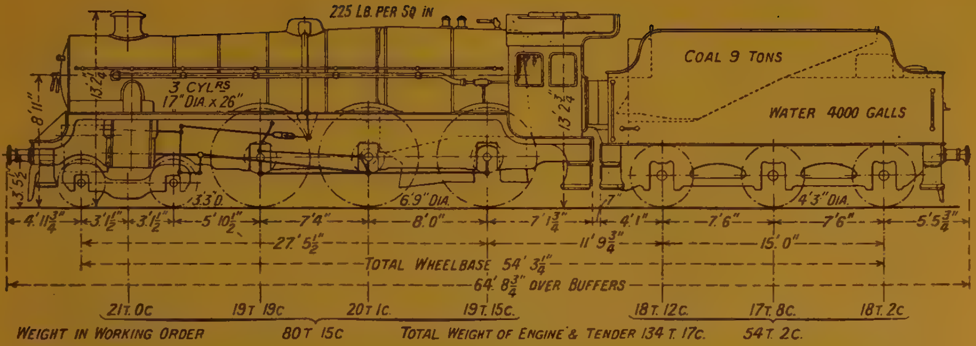


Fig. 10. — Diagram drawing showing principal dimensions and weight distribution with 4 000 gallon tender.

boiler feed is through top feed valves on the second boiler barrel ring with water distributing trays. A Davies & Metcalfe exhaust steam injector is fitted on the fireman's side and a Gresham & Craven live steam injector on the driver's side.

Some of the engines have tenders with coal and water capacities of 9 tons and 4 000 gallons respectively; others have smaller tenders holding 3 500 gallons of water and 7 tons of coal. The cabs fitted to the engines have two windows at the side, one of which is of the sliding pattern.

Our inspection of the locomotives at the works enabled us to form a very favourable opinion of the arrangement of the cab and clear outlook therefrom, and of the general excellence of the layout as a whole.

[621. 33 (45)

Italian railway electrification.

(Electric Railway Traction, supplement to *The Railway Gazette.)*

The abundant water power available in Italy, coupled with the complete lack of indigenous coal, were the chief considerations which, as far back as the 'nineties of last century, caused the Italian Government to give serious thought to electrification. A third, and not much less important reason, was the fact that, except in the great plain of Lombardy, the railway routes traversed hilly country by means of heavy gradients eased by numerous long tunnels. In 1897 the Minister of Public Works appointed a Commission to investigate the question. The Commission recommended that experiments should be made with battery vehicles, with the 650-volt direct-current system, and with 3 000-volt alternating current on the three-phase principle.

Battery traction did not give encouraging results and was soon abandoned, but in 1901 the Milan-Varese line was converted to third-rail 650 volts D.C., and has given successful operation over the intervening 33 years. In 1902 a big step was made by the adoption of three-phase current at 3 400 volts, 15 cycles, on the Valtellina line, from Lecco to Colico, Sondrio, and Chiavenna. The conversion work was carried out by Ganz & Co.,

Fig. 1. — Overhead construction of three-phase lines at crossover road.

Fig 2. — Three-phase electric locomotives and shed at Pistoia.

of Budapest, in conjunction with the railway engineers; and a reduction in gross operating expenses, including interest and depreciation, of 12 % was obtained compared with steam traction.

After the nationalisation of the railways in 1905, attention was concentrated on the possibilities of electric operation, principally with a view to increasing the capacity of certain heavily-graded lines, and one of the most difficult of these, the Giovi line, leading out of Genoa to the north, and handling 80 % of the freight traffic from that port, was electrified in 1910-11 on the three-phase system at a tension of 3 000 volts and a periodicity of 15 cycles. This current, and that used by the Valtellina line, were subsequently altered to the standard 3 600-3 700 volts, 16 2/3 cycles. The Giovi line has a maximum grade of 3.5 %, six tunnels, and numerous curves of 1 300 ft. radius, in the 14.5 miles from Sampierdarena to Ronco, which was the first section electrified. The line from Sampierdarena to Genoa and along the coast to Savona was converted in 1916. The section from Savona to Ceva had already been electrified in 1914 at 3 700 volts three-phase, in order to increase its capacity, and this followed the conversion of the line from Bussoleno to Bardonecchia, part of the main route from France to Turin, electric operation over which commenced in 1912 with three-phase current at 3 300 volts, since converted to the standard 3 700 volts. The extension on to the P.L.M. Railway at Modane was completed in 1914.

During the war, electrification of the lines centering on Turin was commenced, and by 1924 electric operation was in force between Turin and Genoa via the Giovi route, and in 1925-26 was extended southwards along the coast from Genoa to Leghorn. The three-phase system in the north of Italy received further important additions by the conversion of the Bologna-Pracchia-Florence line in 1927, the Sampierdarena-Alessandria and Bolzano-Brennero lines in 1929, and the Savona-Ventimiglia and Cuneo-San Dalmazzo lines in 1931, and finally of the Spezia-Fornovo line in 1933.

Meanwhile, in 1928, the electrification of the Benevento-Foggia line across the main backbone of the Apennines was commenced, but something of a revolution was effected by adopting direct current at 3 000 volts tension. Apparently this has given so much satisfaction that it was used for the 60-mile extension from Benevento to Naples, opened in 1931, and for the new Bologna-Florence *Direttissima*. It has now been adopted as a standard for new construction in those areas away from the Milan-Turin-Genoa-Leghorn three-phase system. The year 1928 also saw another innovation in the introduction of three-phase current at 10 000 volts, 45 cycles, thus overcoming the disadvantages of the low-tension low-periodicity three-phase system, without getting away from the complicated overhead apparatus. The line so electrified was that from Rome to Avezzano, and the extension on to Sulmona was brought into operation at the beginning of 1933.

The State Railways electrified mileage is completed by a number of low-tension D.C. lines, which are detailed in the accompanying table, and by the single-phase Domodossola-Iselle line, which, under the Simplon Convention, is worked by the Swiss Federal Railways. A number of private lines are electrified, and the more important of these, such as the North Milan, the Emiliana, the Rome-Viterbo, the Circumvesuviana, and the Valli di Lanzo, use direct current at 3 000-4 000 volts.

Last year, a programme of widespread railway electrification was announced by the Italian Minister of Communications. The scheme was drawn up in an endeavour to work the lines economically and to prepare for increased traffic in the future, and also to develop Italy's

Fig. 3. — 3 000 volt direct-current overhead lines at Benevento, Italian State Railways.

hydro-electric resources in preference to importing foreign coal, a vital matter in the defence of the country. The full programme covers the conversion of 1 637 route miles of double track and 1 076 route miles of single track, comprising the following lines :

a) Completion of the electrification of the Milan-Reggio Calabria trunk routes via (1) Bologna and Florence, and (2) Genoa and Pisa.
b) Cross-country line from Turin to Trieste.
c) Completion of electrification between Genoa and the Simplon, and between Genoa and the St. Gotthard, via Milan.
d) Completion of electrification of the Ligurian-Piedmontese system, and of the lines in Tuscany bounded by the Genoa-Leghorn line on one side and the Bologna-Florence *Direttissima* on the other.
e) The Udine, Tarvis, Trieste and Fiume lines.
f) The line from Bolzano to Bologna.
g) All lines converging on Bologna.
h) Conversion of Rome-Sulmona 10 000-volt three-phase to 3 000-volt d.c. for the sake of uniformity.

The estimated cost of the conversions detailed above is 4 200 000 000 lire, equivalent to £ 45 400 000 at par, and the work is to be divided into three sections, occupying four years each. The first section is already under way, with conversion work proceeding between Naples and Salerno, and the contracts have now been placed for the conversion of the Fiume and Trieste lines.

Power supply and transmission.

The whole question of electric supply is controlled by the Italian Government as a matter of national importance, although a number of private companies are concerned in the production and transmission. The economic side of electricity supply favoured the linking up of the railway transmission system with others already in existence, and that the railways should have their own power

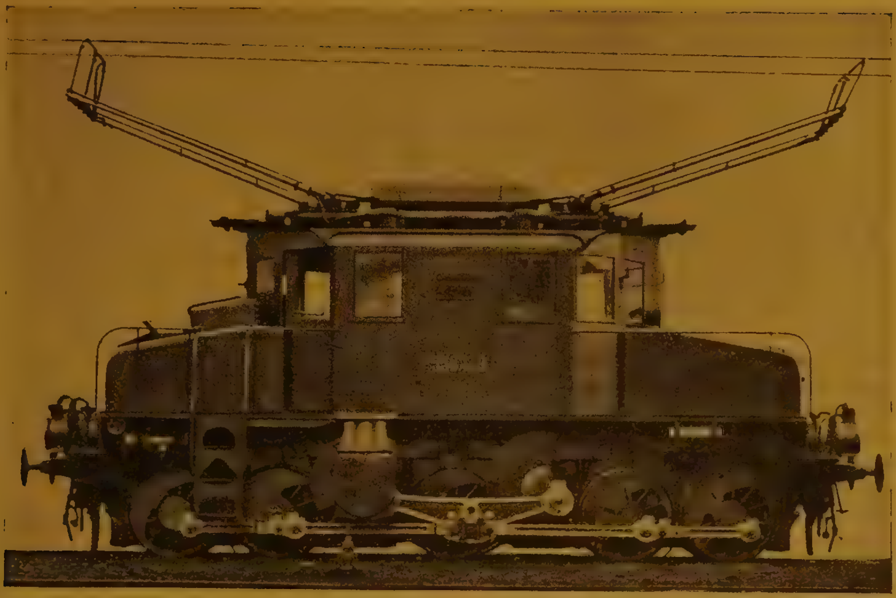


Fig. 4. — Standard E-type three-phase goods locomotive, Italian State Railways.

Fig. 5. — 3 000-volt direct-current express electric locomotive, Italian State Railways.

stations only in certain cases where technical or out of the ordinary reasons should warrant the capital expenditure. In compliance with the general electrical policy the railway administration decided upon the application of 3 000-volt D.C. to the Benevento-Foggia line and 10 000-volt three-phase current at the industrial frequency of 45 cycles to the Rome-Sulmona section.

Oldest of all the railway-owned power plants is that at Morbegno on the Valtellina line, which was erected in 1901-02. Other hydro-electric stations are located at Bardonecchia, Pavanon and Sagittario, and there is also a steam power station at Chiappela, near Genoa. A number of private distribution companies also supply current for railway purposes. In general, the State transmission lines are of 60 kV., but tensions up to 150 kV. are used by certain supply companies.

Low-tension three-phase system.

The three-phase network which covers Liguria and Piedmont is fed from various hydro-electric stations in the Alps and Apennines, and by steam power stations at Chiapella and Savona. Standardised substations are provided, containing four, seven, or nine single-phase oil-immersed transformers, the capacity varying from 600 to 1 750 kVA. The distance apart averages nine miles, but no greater distance than 20 miles is allowed, as the power of the three-phase motors falls very rapidly with a drop in the voltage. As a reserve to the static transformer substations, a number of mobile substations, each with a capacity of 2 250 kVA., are in service. These vehicles, which weigh 90 tons and run on two six-wheeled bogies, step the current down from 60 to 3.7 kV., and experience has shown them to be so satisfactory that in some cases they are used instead of the ordinary type, being much cheaper to build.

New lines.

One of the most important divisions recently electrified on the three-phase system at 3 700 volts is the difficult line from Spezia to Fornovo, which is used by certain Rome-Milan expresses. Actually, the Fornovo line has a double junction with the Leghorn-Genoa line, at Vezzano and Sarzana, the former place being 3.1 miles distant from Spezia. The electrification of this line, with a route mileage of 59, involves the consumption of 20 000 000 kw.-h., and an annual saving of 40 000 tons of coal, and was carried out at a cost of 56 077 000 lire. A central substation has been erected at Pontremoli, which is operated by the supply company, and takes 60 kV. current from the Valtellina power plants, but the supply for the line is augmented from the Ozola, Predare, and Ligonchio electric centres which are connected to Aulla substation by two independent transmission lines. The railway-owned lines run from Aulla and Pontremoli to three further substations, all of which, except that at Fornovo, are of the outdoor automatic type. The Fornovo substation will ultimately house converting plant for the supply of the Bologna-Milan line when this is eventually electrified. The cost of electrifying the Spezia-Fornovo line amounted to approximately 1 000 000 lire per mile, but enabled the time between Milan and Rome to be reduced by an hour, and allowed heavier trains to be run.

Another new three-phase line of importance is the coastal extension from Savona to Ventimiglia, but full benefit from the electrification of the line from the latter place to Cuneo can hardly be felt until the short section passing through French territory is also electrified. Along the coast the maximum inclination is 0.9 %, but on the 11-mile section inland to Piena the average grade is 1.27 % and the maximum 2.5 %. There are eight substations, at Piena, Venti-

miglia, Taggia, Diano Marino, Albenga, Varigotti, and Lavagnola (Savona), and the whole conversion scheme cost 44 560 000 lire, apart from new rolling stock. It is now possible to travel right along the coast from Ventimiglia through Genoa to Leghorn, a distance of 209 miles, by low-tension three-phase electric traction, but this is exceeded by the 284 miles from Modane through Genoa to Leghorn.

High-tension system.

The only line operating on high-tension industrial frequency three-phase current is the Rome-Avezzano-Sulmona line across the Apennines, the 64.25 miles from Rome to Avezzano of which were opened in 1928 and the remainder in 1933. There are grades as steep as 3.15 %, and the line contains numerous sharp curves. Power is supplied from the State Railways' plant at Sagittario, close to Sulmona, which has an annual output of 60 000 000 kw.-h., some of which, however, is used by the high-tension D.C. line from Naples to Foggia, and a small amount locally for general purposes. The increase in the periodicity of the current compared with that of the Ligurian-Piedmont three-phase system has led to geared motors being employed in the locomotives, although the Scotch yoke is retained for the final drive from the jackshaft to the wheels. On the 3 700- volt, 16 2/3-cycle locomotives all the traction motors are gearless, the drive being of the type shown in figure 5.

High-tension D.C. lines.

The tenth anniversary of the Fascist march on Rome was celebrated in November, 1931, by the inauguration of a number of important public works, including the completion of the electrification of the Naples-Foggia main line on the high-tension D.C. system. The 63 miles from Benevento to Foggia were put into electric operation in 1928 and formed the first portion of the Italian State Railways on which 3 000-volt D.C. was used. The time for steam trains over the 123 miles from Naples to Foggia was 5 hours, and although a speeding up and increase in capacity would have been possible by doubling the line, the cost of this would have been excessive. When conversion work was being carried out, opportunity was taken to lay heavier rails, and improve the alignment in certain places, the combined result being the reduction in end to end time to 3 1/2 hours. In steam days, 56 engines were required to handle the traffic, whereas 23 electric locomotives are now sufficient, and are able to haul roughly twice the weight at twice the speed over the maximum grade of 1 in 44.

The principal technical feature of the Naples-Foggia line is the use of mercury-arc rectifier substations, and the Benevento-Foggia section was probably the first main line in the world to be fed throughout by substations of this type, and the first line to use rectifiers for so high a tension. There are only six substations on the whole line, and the standard rectifier unit is of 2 000 kw. capacity, made up in banks of two or three units in the various stations. The maximum distance between the substations in 28 1/2 miles, and the substations are fed with 118-kV. current from the Sagittario plant.

Bologna-Florence Direttissima.

By far the most important event connected with Italian electrification in recent years has been the completion, and opening on April 21, by the King of Italy, of the Bologna-Florence direct line, which has been under construction since 1913. The line is double track throughout, and has a maximum grade of 1.2 %, against the 2.56 % of the old line via Pracchia, and the distance from Bologna to Prato, where the new line joins

Fig. 6. — Map of Italian electrified lines, showing various types of current used.

the old, is 52.2 miles compared with 73.4 miles by way of Pracchia. But due to the reduction in current consumption consequent upon the easier grades, the *Direttissima* is equivalent, on the current consumption basis, to a reduction of 48 % in the mileage when going south from Bologna, and 38 % in the northbound direction.

The importance of the *Direttissima* lies not so much in the saving of 21 miles of route or of a relatively large amount of current, but in the accelerations between Central Europe and Rome which are rendered possible. For instance, the present best time of 8 1/4 hours over the 392 miles from Milan to Rome is an acceleration of 85 minutes on the pre-

TABLE I. — **Electrified lines of Italian State Railways.**

Line.	Electrified mileage.		Voltage.	System.	Conductor.	Year electrified.
	Route.	Track.				
Milan-Varese-Porto Ceresio	45.1	94.7	650	D.C.	3 R	1901-2
Lecco-Sondrio-Colico-Chiavenna (Valtellina)	65.0	77.0	3 700*	3/16 2/3	O H	1902
Sampierdarena-Ronco (Giovi)	38.0	106.0	3 700	3/16 2/3	O H	1911-15
Turin-Modane	69.0	166.0	3 700	3/16 2/3	O H	1912-20
Savona-Ceva	28.0	48.0	3 700	3/16 2/3	O H	1914
Lecco-Monza	22.7	40.0	3 700	3/16 2/3	O H	1914
Sampierdarena-Savona	25.0	35.0	3 700	3/16 2/3	O H	1916
Turin-Torre Pelice-Barge and Sangone-Chieri	61.3	88.8	3 700	3/16 2/3	O H	1917-21
Turin-Ronco, Alessandria-Voghera, Tortona-Novi-Arquata	151.6	403.0	3 700	3/16 2/3	O H	1921-24
Genoa Harbour	14.0	20.0	3 700	3/16 2/3	O H	1924-26
Genoa-Leghorn	120.0	270.0	3 700	3/16 2/3	O H	1925-26
Bologna-Piaccha-Florence	†77.0	138.0	3 700	3/16 2/3	O H	1927
Bolzano-Brennero	55.0	141.0	3 700	3/16 2/3	O H	1929
Sampierdarena-Ovada-Alessandria	45.8	60.0	3 700	3/16 2/3	O H	1929
Cuneo-S. Dalmazzo, Piena-Ventimiglia	46.5	28.0	3 700	3/16 2/3	O H	1930-31
Ventimiglia-Savona	67.0	77.0	3 700	3/16 2/3	O H	1930-31
Fornovo-Sarzana-Vezzano	59.3	79.0	3 700	3/16 2/3	O H	1932
Rome-Avezzano-Sulmona	108.0	150.0	10 000	3/45	O H	1928, 1932
Domodossola-Iselle±	11.9	34.4	15 000	1/16 2/3	O H	1930
Foggia-Benevento	63.0	93.1	3 000	D.C.	O H	1927-28
Benevento-Naples	60.0	123.0	3 000	D.C.	O H	1930-31
Florence-Bologna (Direttissima)	60.7	135.0	3 000	D.C.	O H	1934
Aosta-Pre St. Didier §	19.0	25.0	3 000	D.C.	O H	—
Naples-Villa Litorno	22.9	69.0	750	D.C.	3 R	1925-27
Trento-Male	37.0	41.0	800	D.C.	O H	1919
Brunico-Campo Tures	9.5	10.3	800	D.C.	O H	1919
Total . . .	1 382.3	2 552.3				

* Originally 3 000 volts 15 cycles.
± Worked by Swiss Federal Railways.
† 87.5 miles until opening of Direttissima.
§ Purchased by State Railways in 1931.

TABLE II. — **Electrified private railways in Italy.**

Railway.	Electrified mileage.		Voltage.	System.	Conductor.	Year electrified.
	Route.	Track.				
North Milan: Milan-Saronno, Milan-Meda	31.0	80.0	3 000	D.C.	O H	1929
Emiliana	71.5	90.0	3 000	D.C.	O H	1930-32
S. Severo-Peschichi	49.0	55.0	3 000	D.C.	O H	1931
Voghera-Varzi	20.5	30.0	3 000	D.C.	O H	1932
Rome-Viterbo	65.0	70.0	3 000	D.C.	O H	1932
Rome-Ostia	16.0	?	3 000	D.C.	O H	1928
Turin-Ceres	26.5	40.0	3 600	D.C.	O H	1921
Central Umbria: Umbertide-Terni, etc.	70.5	85.0	11 000	1/25	O H	?
Other Lines (including light railways)	840.0	?	Various.	Various.	Various.	1914-33
Total	1 190.0					

vious best timing over the 413 1/2 miles of the old route. Together with improvements in connections at Milan, and the institution of several new Milan-Rome services, the cuts in long-distance journey times to and from Florence and the Italian capital will in several cases amount to 3 1/2 hours.

As may be seen from the accompanying map, the *Direttissima,* on leaving Bologna, crosses the Savona torrent and continues on the right bank as far as Pianoro. The great massif of Monte Adone is negotiated by means of a 4 1/2-mile tunnel, from which the line follows the Setta valley, runs through Pian di Setta tunnel, 1.9 miles, and then enters the chief work of the whole line, the great Apennine tunnel, 11 1/2 miles long, second only to the Simplon among the world's railway tunnels. The summit level of the line, 1 072 feet above sea-level, compared with the 2 034 feet of the Pracchia line, is reached in the tunnel,

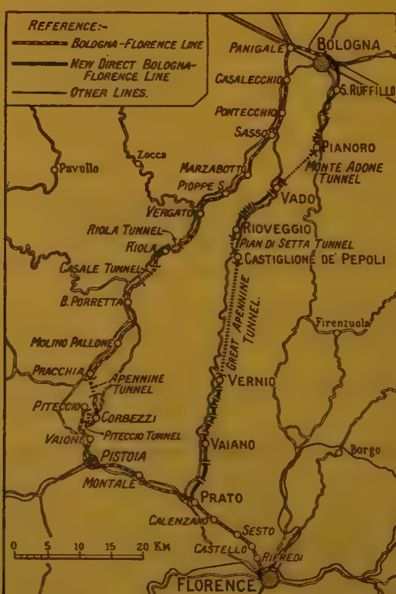


Fig. 7. — Map of Florence-Bologna Direttissima line.

from which the line falls to Prato, where the old route is joined. The line is entirely free from level crossings, but runs through 30 tunnels, with an aggregate length of 22.9 miles, and over 41 bridges and viaducts. Eight new stations have been built, including that at Prato, where the old station has been closed.

Although shorter than the Simplon, the Apennine tunnel is of much greater cross-section, as one bore houses both tracks, the section being 29 ft. by 26 ft. against 16.5 ft. by 19.5 ft. There is a station in the middle to enable fast trains to overtake slower traffic. The excavated material amounted to 53 000 000 cu. feet, and the masonry lining to 15 500 000 cu. feet; the electric current consumed during the construction was 113 000 000 kw.-hours, and the amount of dynamite, 981 tons. The total cost of the tunnel was 470 000 000 lire (£ 5 080 000 at par or £ 7 850 000 at the present rate of exchange), and that of the Setta tunnel 60 000 000 lire, or £ 650 000 at par, so that of the total cost for the whole line of 1 200 000 000 lire (£ 13 000 000 at par, and £ 20 000 000 at present rate), something like 65 % has been required for tunnelling works. Moreover, the bridges and earthworks are very heavy, so that only a small proportion of the total cost has been expended on electrification work.

Electrification.

Electrification at 3 000-volt D.C. was decided upon as a result of experience gained on the Benevento-Foggia section. Three-phase current at 60 kV. is supplied to seven mercury-arc rectifier substations from Bologna distribution centre. The overhead contact lines are independent of one another, and are supported by side catenaries, with automatic tensioning devices. The old Florence-Bologna line, via Pracchia, was electrified on the 3 700-volt three-phase system in 1927, but the section from

Prato to Florence has now been converted to 3 000 volts D. C.

The locomotives used on the *Direttissima* are all either duplicates or developments of those used on the Naples-Foggia division. Express passenger traffic is handled by $2\text{-}C_0\text{-}2$ locomotives of class E.326, but a new $2\text{-}B_0\text{-}B_0\text{-}2$ type is under construction for the heaviest work. Both types have double-armature spring-supported motors with the Bianchi form of quill drive. $1\text{-}D_0\text{-}1$ locomotives of similar appearance, and classified as E.625, are used for goods trains. It may be of interest to record that the Metropolitan-Vickers Electrical Co. Ltd. in 1926 supplied complete electro-pneumatic control equipment for three of the 2 220 H.P. locomotives then being built for use on the Benevento-Foggia line.

Fig. 8. — Passing station in the centre of the great Apennine tunnel under construction.

The latest type of express locomotive in actual service is illustrated in figure 5. It is understood that locomotives of this type have recently been tested on the line at speeds varying from 90 to 95 m.p.h., although in normal service they will probably not exceed the usual maximum speed of 75 m.p.h.

Table I shows that almost 1 400 route miles of State-owned line in Italy are now operated electrically, and it is anticipated that by the end of the present year another 50 miles will be con-

Fig. 9. — Tensioning device for contact lines as used on the Florence-Bologna Direttissima.

verted. At the end of 1932, when approximately 1 260 miles of line were in regular electric operation, traffic was worked by 873 locomotives, and the lines fed through 105 substations with a total capacity of 483 000 kVA. Power was then produced in 24 power stations with a capacity of 357 200 kVA., and the high-tension transmission lines extended over a length of 3 000 miles. One-third of the power stations belonged to the State, and two-thirds to private companies.

On this electrified system, representing approximately 12 1/2 % of the total State-owned mileage, was carried one-third of the whole traffic. The total power consumption of 390 000 000 kw.-hours represented the equivalent of an annual saving of 590 000 metric tons of coal.

[625. 212 & 625. 143.3]

Rail and flange lubrication.(1)

A review of the problem, the devices available to meet it, and the economies possible,

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Rail and flange lubrication has interested the steam railways only during the last 10 or 15 years, and it has only been during the last 7 years or more, with the development of satisfactory curve lubricators for installation in the track, that the practice of lubricating wheel flanges and curved rail has become thoroughly practical and economical. Today there are hundreds of track lubricators in service on the railways, and it is only reasonable to assume that as the merits and economies of these devices are more generally and fully appreciated, there will be many additional installations.

Curve lubricators, not track oilers.

The term « Track Oilers », as used quite generally, is misleading and a misnomer. Most persons think of track oilers as the spraying equipment used to coat the rails and their fastenings with an asphaltic oil to protect them against the corrosive action of brine from refrigerator cars. The correct term, when referring to devices attached to the rail and designed to put a coating of lubricating oil or grease on the wheel flanges of cars and locomotives, and thus reduce flange and rail wear on sharp curves, is « track lubricators », and the results secured should be termed « curve lubrication » and not curve oiling.

The problem of preventing the excessive wear of rails on sharp curves, as well as that of reducing the annoying « squeal » of wheels on these curves, was encountered years ago by the street, subway, and elevated railways. Their problem was met by the hand application to the rail of either a heavy asphaltic oil or a grease containing a good percentage of graphite. In the case of the steam railroads, the advent of the larger locomotives and heavier rails accentuated the wear on both the rail and wheel flanges, and hand methods of

(1) Presented before the Metropolitan Track Supervisor's Club at New York.

lubrication proved inadequate and too expensive for widespread use. The large potential savings on the railways through the reduction of wheel flange and rail wear prompted work on a feasible solution of the problem in both the mechanical and track departments. Lubricating devices were developed and have been promoted in both departments, but it has been proved finally that an automatic device attached to the rail is the more reliable and economical method of lubrication of rail.

The various methods of flange lubrication tried by the mechanical department have included devices for applying oil, grease and stick graphite directly to locomotive tire flanges. The oil and grease methods were of two general types. One type was hand-operated by the fireman when reaching curves. The other type was supposed to be automatic and usually employed centrifugal force to open a valve when going around curves. The results obtained by this latter method varied with different speeds of the train. The graphite stick method operated by having the stick in contact with the wheels at all times, spring action or gravity being employed to keep the feed continuous. Locomotive flange lubricators apply lubricant on locomotive wheels only. For this reason, with this type of lubricator, it is seldom possible to transmit sufficient lubricant to the curved rails to protect them against wheel flange wear, except in the case of the first few cars directly back of the locomotive.

Curve lubricators attached to the rails.

The first lubricators designed for the track department used oil as the lubricating agent. Early it was found that heavy oil is more efficient than light oil, since it has more body, and that asphaltic base oils adhere to the wheels longer. This is important in high-speed territory since centrifugal force tends to throw the lighter oils off from the wheels. This same action tends to make the oil run to the bottom of the wheel flanges. Heavy oils, on the other hand, were found to change their consistency considerably at low temperatures. Thinner oils were tried, but these lighter body oils afforded less protection. Certain heavy oils with a small percentage of graphite gave about the same results as aphaltic oils.

In addition to the troubles encountered by the varying consistency of oils due to changing temperature, trouble was also encountered in connection with the application of locomotive sand on grades and in yard districts. This was true particularly with lubricators that had a semi-open container on the gage side of the rail. Several lubricators were devised to squirt oil on the wheel flanges or rail head, and thus overcome most of the sanding problem, but these machines still had the problem of the changing viscosity of oil.

The oil lubricators developed are operated by several methods, among which are the following :

1. Wave motion of the rail, operating ratchets or plungers.
2. Plungers operated by the flanges of the wheels.
3. Ramp levers operated by the flanges of the wheels, which, in turn, make use of ratchet cranks or plungers.
4. Motors, controlled by track circuits.

The first grease lubricators developed made use of heavy greases, similar to that used for hand application by the elevated and subway railways. These greases were not entirely adapted to use in automatic grease lubricators, especially because they contained small solid particles which frequently plugged the discharge orifices of the lubricators, and therefore required considerable cleaning and maintenance. At present there are several greases on the market which have been made especially for

use in automatic lubricators, and which permit continuous operation of these machines with very little maintenance.

From the first, it was found that grease lubricators gave evidence of greater carrying ability than the older types of lubricators. Weather and sanding conditions have little effect on their operation. It was also noted that the degree of protection was increased by the use of greases containing from 15 to 20 % of graphite.

Grease will adhere to the wheel flanges where it is applied, and, as a result, it is possible to apply it to the curved throat of the wheel flanges without danger of getting it on top of the rail. Centrifugal force at high speeds has little effect in throwing grease off the wheels after application, which results in a cleaner appearance of the track and a saving in grease. In other words, grease stays on the wheels until it is removed by contact of the wheels with the gage side of the rail head. This means that greater « carry » of the grease is obtained and makes it possible to lubricate several curves with one lubricator, even though certain of them are a mile or more from the lubricator.

It has been found that by making use of the overhanging edge of the wheel tread to operate the pumping mechanism of a lubricator, a more uniform discharge of lubricant can be obtained. This is because there is little variation in the treads of the wheels.

Proper location of lubricators.

The location of lubricators is often a very important factor in the character of the lubricating results obtained, and varies with different types of lubricators. The location is also affected considerably by such local conditions as traffic, grades, the number and spacing of the curves to be protected and whether the installation is to be in single or in multiple-track territory. In general, the grease lubricator is located in tangent track, ahead of the elevated easement. This allows the wheels to contact the grease, without squeezing it up on to the wheel tread or forcing it too low on the flanges. Properly applied in this manner, the grease adheres to the wheel flanges where it is available for the lubrication of the curved rails when the flanges come in contact with them. The specific location of the lubricator should be near the point of curve where a neutral condition of wheel thrust is encountered, as indicated by equal flange wear on both rails.

In double-track territory, or where traffic is in one direction most of the time, the lubricator should be placed in the tangent just ahead of the curved territory to be lubricated. If the curved territory has more curved rail in it than can be protected by one lubricator, additional lubricators should be installed where the lubrication from the preceding lubricator appears to be insufficient to carry around the next curve.

In a great number of locations, careful consideration of the existing physical conditions is advisable. In single-track territory, or where traffic operates in both directions over the same track, the lubricators should be placed in tangents somewhere in the curved territory. Usually, the first lubricator should be placed so that the amount of curved rail between the lubricator and the end of the curved territory is equal to about half the normal curve-protecting ability of the lubricator. This is because this first lubricator must lubricate the curved section ahead of it sufficiently for trains in both directions, while utilizing traffic in one direction only for applying the lubricant to the rail. When only a single curve subject to two-way traffic is to be protected, as is often the case where there is a single sharp curve in an otherwise light-curve territory, it is well to consider most carefully the type

of lubricator to be used and the best location for its installation.

Rail and flange lubricators are used to large advantage within terminals and yards. In this service a lubricator can be placed to take care of an entire ladder track, protecting not only the switch points, but also the curved leads and any curves in the same direction on the tracks beyond. The location for this type of service is usually on pull-in or hump tracks. The grease type of lubricator is especially adaptable to this service since it is troubled less by sand and variable speed. The benefits of lubrication applied to wheels in equipment entering a terminal are frequently extended to outbound routes by means of the grease that remains on the wheels.

Advantages of lubrication.

In thinking of rail and flange lubrication, most track men are inclined to consider it only from the standpoint of the savings effected as a result of the increased life of rails. This is only one of the many savings effected, and amounts to only a little over half of the actual savings possible. Wherever lubricators have been used to any extent, good reports have been given as regards savings from the following additional factors :

1. Reduction in expense for the lining and surfacing of curves.

2. Reduction in the amount of track re-gaging.

3. Reduction in the amount of flange wear on car wheels and locomotive tires.

4. Increased tonnage rating due to the reduction of train friction resistance.

5. Increased speed of operation on curves with safety as a result of the elimination of the hazard of derailments due to sharp wheel flanges.

Naturally, it is advisable to calculate the savings that will accrue from the use of rail lubricators before deciding on their use. From the standpoint of the track department, this calculation is relatively simple. In general, it is economical to lubricate curves where the rail, because of flange wear, has to be renewed within six years. It should be remembered that it is the amount of curved rail protected and not the distance the lubricant carries, which is important.

Rail lubricators, like all machines, demand care. The results obtained from them are in direct proportion to the interest shown by those who have charge of them. Proper care in keeping foreign material out of the grease is important. It is also important to make occasional inspection of the lubricators to see that they are operating properly.

One of the most important factors in the satisfactory and economical operation of an automatic rail and flange lubricator is the use of a proper lubricant. The lubricant used, more than any other factor, is the cause of varying results obtained by different roads. In this connection, it should be borne in mind that the lubricator is really only a device for pumping whatever lubricant is used, to a position where the wheels can come in contact with it as they pass the machine. The amount of lubrication obtained and the cost of maintaining lubricators vary considerably with different greases. It is important to keep in mind, therefore, that it is not the first cost of a lubricator that is the most important, but rather, the ultimate cost of adequate lubrication per foot of curved rail.

MISCELLANEOUS INFORMATION.

[625. 232 (44)]

New light-weight Italian coaches.

Steel-framed vehicles incorporating aluminium wherever possible.

(From The Railway Gazette.)

A new type of passenger coach has recently been put into service on the Italian State Railways. In order to reduce weight, light metals have been employed wherever possible without impairing rigidity. Notwithstanding the greater weight of the bogies, the wheel-

Fig. 1.

base of which was increased from 2 500 m. (8 ft. 2 1/2 in.) to 3 000 m. (9 ft. 10 in.), it has been found possible to reduce the weight per seat — as can be seen from the following comparative table for the years 1921 and 1932 :

	Weight	Number of seats			Weight per seat, kgr. (*lb.*)		
		1st	2nd	3rd	1st	2nd	3rd
1921	42 800 kgr. = 42 tons 2 cwt.	42	64	80	1 018 (*2 245*)	669 (*1 475*)	535 (*1 180*)
1932	42 800 kgr. = 42 tons 2 cwt.	48	72	88	889 (*1960*)	593 (*1 308*)	485 (*1 069*)

The principal dimensions of the new coaches are:

Length over buffers	23.210 m. = 76 ft.
Distance, centre to centre of bogies	16.170 m. = 53 ft.
Bogie wheelbase	3.000 m. = 9 ft. 10 in.
Maximum external width	2.928 m. = 9 ft. 9 in.
Internal width	2.810 m. = 9 ft. 2 1/2 in.

The general characteristics of the frame and body do not differ much from the usual type. The sides are of 5/32 inch copper-bearing steel sheets. The roof is of aluminium in the centre and iron at the sides. The londitudinal partitions between corridor and compartments are fixed at the top over their whole length to a special V-shaped aluminium girder, which in its turn is firmly secured to the roof. At the bottom these partitions are fixed to plates projecting from the frame slighly. The partitions themselves are

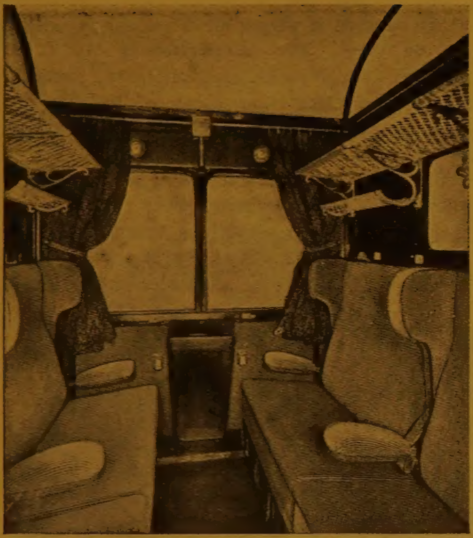

Fig. 2. — Second-class compartment.

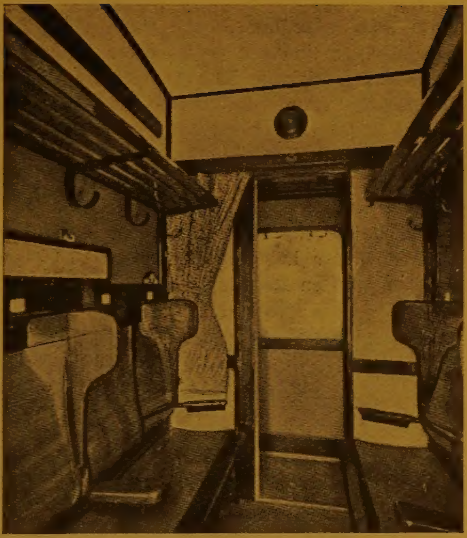

Fig. 3. — Third-class compartment.

composed of aluminirum sheets within a wooden frame-work. The cross partitions between the compartments are of aluminium sheets fixed at the bottom to the frame, and on their sides to the vertical pillars of the body and to the girder of the longitudinal partition respectively. The partitions of the lavatory are of steel. All wooden framework is of teak.

The internal decoration is very pleasing. In the first class carriages the visible woodwork is mahogany, in the second and third class

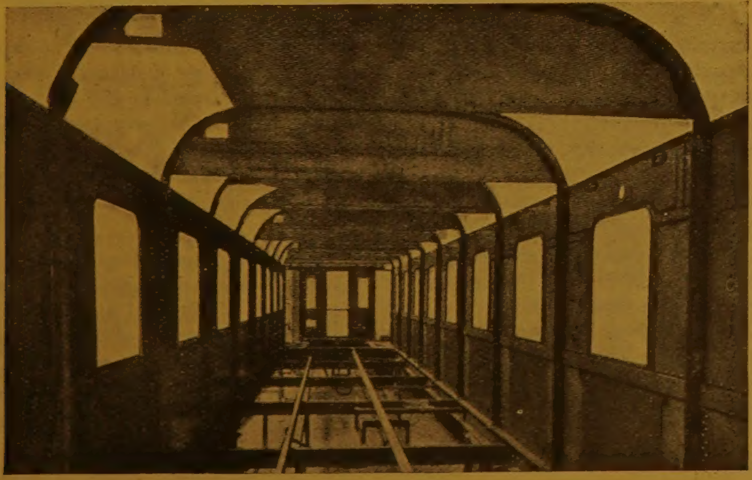

Fig. 4. — Walling, floor frame, and traverse roof ribs erected.

teak, and, according to the class, velvet, or pegamoid or linoleum is used for lining the walls and partitions. The lavatories are white enamelled. The construction of the seats differs from the previous types, the framework being of aluminium and carrying special spring cushions which can easily be removed and cleaned.

The main floor is of corrugated aluminium covered with a layer of compressed cork over which a wooden floor is laid, and this in turn is covered with carpet or linoleum according to the class. The compartments are fitted with the usual racks, etc., all metal parts in first and second class being of bronze, and each compartment is provided with two extractor ventilators.

The lavatory basins are fitted with a special anti-waste device which, when the tap is turned on, discharges only a measured quantity of water. The lavatory floors are composed of a grid of cast aluminium alloy which

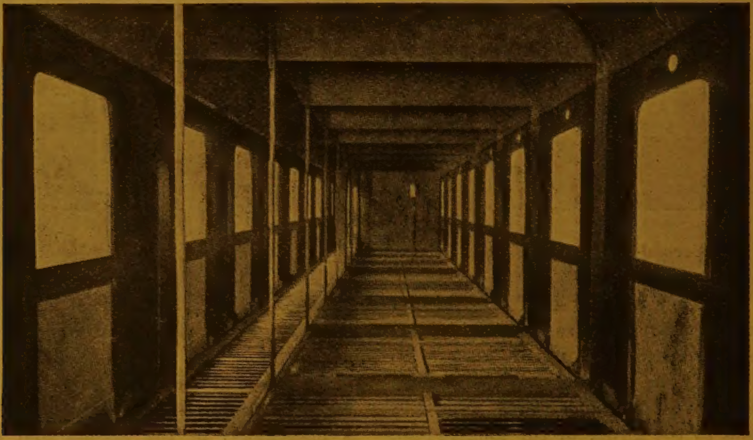

Fig. 5. — Corrugated aluminium flooring in place.

is fixed a certain distance above a lower floor of white enamelled aluminium alloy. This floring has proved a great success, as no water can collect on the gridlike upper floor. The tanks have a capacity of 75 gallons of water.

The doors at each extremity of the corridor are constructed in light metal. To ensure hermetic closing, a soft rubber packing is fitted in special grooves all round. All opening windows have metal frames and are equipped with the special balancing device of the State Railways. The heating radiators in the compartments are of aluminium. In order to avoid the harmful effects of expansion, the main steam pipe underneath the carriage is fixed to the frame in the centre, and is free at the ends. The carriages are illuminated, in the standard method used by the Italian State Railways, from eight accumulators, which provide sufficient current for about 38 hours.

Our first illustration depicts one of the second-class coaches, but the third-class are very similar in general appearance except that only single instead of double windows are provided for each compartment.

OBITUARY.

José GAYTAN de AYALA,

Former President of the Public Works Council, Spain,
Life Member of the Permanent Commission of the International Railway Congress Association,
President of the XIth Congress (Madrid) of this Association.

We have learnt with deep regret of the death of Mr. José Gaytan de Ayala, former President of the Spanish Public Works Council, who was the President of the Madrid Congress, in 1930, and a life member of the Permanent Commission. All those present at that Congress will remember how successfully he carried out this burdensome and thankless task, his first action being the noteworthy speech he made at the opening meeting on the 5th May, 1930.

Mr. José Gaytan de Ayala was born in 1861 and completed his studies as an engineer in the roads, canals, and harbours service in 1885. After having carried on this profession for some time in the province of Guadalajara, he returned to San Sebastian, his native town. There he played an active part in industrial affairs and the town owes much of its progress to his initiative and energy. His outstanding personality won him general esteem and led to his election as deputy to the Cortès, where he was able to make full use of his conciliatory spirit.

His devotion to public affairs was wholehearted and disinterested ; the increased wealth of his native province was largely due to him, owing to the part he played in developing its water power.

In the Public Works Council, of which he later became President, he was much esteemed for his wise and enlightened opinions. His greatest services were to the Railway and Staff sections. His great influence was due, not only to his great knowledge, of which he made no display, but rather to his oustanding personality, generosity of spirit, and uprightness of character.

As leader of the Local Commission of the XIth Session of the Congress, he was able to make use of his gifts as an organiser. Our Association owes to his inspiration the arrangements which assured the great success of the 1930 Congress, of which he was unanimously elected the President. Everyone knows with what devotion and tact he carried out his responsible duties, thereby earning our lasting gratitude.

His death, which is a great loss to Spanish engineering, will be deeply regretted by all the members of our Association.

We offer his family our sincere sympathy.

The Executive Committee.